The Contribution of Agriculture to the Wisconsin Economy

AN UPDATE FOR 2022

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Executive Summary

This study provides an update on the Contribution of Agriculture to the Wisconsin Economy undertaken by Deller (2019) using data for 2022, the most current available. Despite the declining number of farms between 2017 and 2022 (from 64,793 in 2017 to 58,521 in 2022, see Hadachek and Deller 2024) there was an increase in the number of food processors (including beverage manufacturers) over the same period (1,160 in 2017 to 1,245 in 2021 (most current year available). Together, the Wisconsin agricultural production and food processing sectors contributed a combined $116.3 billion in industrial revenues in 2022 (14.3% of the state total), an increase of 10.9% from 2017. The contribution to employment, however, declined from 437,700 jobs in 2017 to 353,900 jobs in 2022, a decline of 19.1%. Labor income (wages, salaries, and proprietor income) decreased by 5.5% going from $22.5 billion in 2017 to $21.2 billion in 2022. There was a modest increase in total income (labor income plus all other sources of income), going from $37.6 billion in 2017 to $37.78 billion in 2022.

- "All agriculture", combined on-farm and food processing, contributes $116.3 billion (14.3% of the state total) to industrial sales or revenues, 353,900 jobs (9.5% of the state total), $21.2 billion to labor income (8.7%), and $37.8 billion (9.4%) to total income.

- On-farm activity contributes $30.5 billion to industrial revenue (3.7% of the state total), 143,690 jobs (3.9%), $6.4 billion to labor income (2.6%), and $13.7 billion to total income (3.4%).

- Food processing, including beverages, contributes $107 billion to industrial revenues (13.1% of state total), 298,400 jobs (8.1%), $18.7 billion to labor income (7.7%), and $32.4 billion to total income (8.1%).

- Dairy, both on-farm and processing (which is dominated by cheese production), contributes $52.8 billion to total industrial revenues or sales (6.5% of state total), 120,700 jobs (3.3%), $7.9 billion in labor income (3.2%) and $13.7 billion in total income (3.4%). It is important to note that dairy processing accounts for much of the contribution of dairy.

- "All agriculture" in Wisconsin contributes 17 million metric tons of CO2 equivalent (MMTCO2eq) in greenhouse gas emissions or 14% of statewide emissions. Approximately 7 MMTCO2eq are associated with dairy production in the state.

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Introduction

Agriculture is an integral part of Wisconsin's culture, where the agricultural heritage is celebrated and cherished by residents, contributing to a strong sense of pride in Wisconsin's rural roots and agrarian traditions. The Green Bay Packers are named after their initial sponsor the Indian Packing Company, a meat packing company who provided funding for team equipment and uniforms and provided the facilities for practice and games. The Milwaukee Brewers selected the name to reflect the city's strong association with brewing and beer production, including famous breweries such as Pabst, Schlitz, and Miller. Whether it is the "Sausage Race" at Brewer's games or the pride of wearing cheesehead hats, agriculture is engrained in Wisconsin. Agriculture has also been documented as a fundamental part of the Wisconsin economy (i.e., Deller 2004; Deller and Williams 2009; Deller 2014, 2019). The current study is intended to build off the recently released 2022 Census of Agriculture and update the contribution of agriculture to the Wisconsin economy.

To be consistent with prior studies, we define agriculture as composed of two parts: (1) on-farm production or "inside the farm gate" and (2) food processing or "beyond the farm gate". For Wisconsin, these two parts of agriculture are integral to each other and could be considered two halves of the same whole. Wisconsin, for example, proudly refers to itself as "America's Dairyland", where dairy farms and cheese processors are intertwined. Indeed, nearly 90 percent of milk production in Wisconsin goes to the production of cheese. Further, both the Packers and Brewers are named after food processing where significant value is added to raw farm products. For this study, we explore both on-farm production and food processing independently and aggregated together. We also explore the dairy industry separately and as part of the broader Wisconsin agricultural economy. Finally, we also explore the contribution of forestry-related activities (including the more modest hunting, trapping, and seafood sectors) as a unique part of the Wisconsin economy.

The report is composed of several sections including historical trend analysis, economic cluster analysis, and the contribution to the Wisconsin economy analysis. As in prior studies in this line of work, we conduct the analysis at the state level and the eight subregional groupings of counties (defined

as the National Agriculture Statistical Services reporting districts). A new component of the analysis is a detailed assessment of the environmental impacts of agriculture using measures related to air pollution, water pollution, and water use.

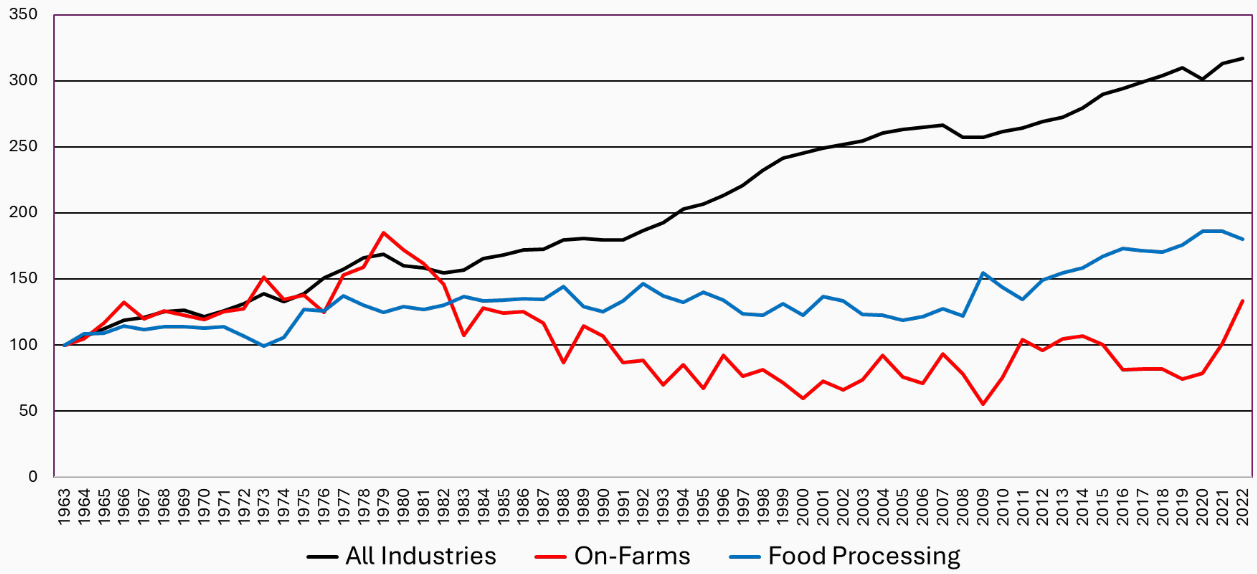
Historical Trends

In a simple analysis of the two most recent Census of Agriculture (2022 and 2017), Hadachek and Deller (2024) noted that despite a relatively stable period in the number of farms between 1997 to 2007, Wisconsin lost 6,272 farms between 2017 and 2022, a 9.7% decline. Over the 25-year period (1997 to 2022) Wisconsin went from 79,541 farms to 58,521, a loss of 21,020 farms or 26.4%. This rate of decline in the number of Wisconsin farms was faster than the national average, which experienced a 14.2% decline between 1997 and 2022 and 6.9% between 2017 and 2022. At the same time, there was stable growth in the number of food processors (e.g., cheese, canning, breweries, etc.). From 2012, the number of food processors increased from 1,056 to 1,245 firms in 2021, an increase of 17.9%. Correspondingly, employment in food processing increased 28.2%, going from 65,040 to 83,400 jobs.

While tracking the number of farms and food processors over time is one way to explore historical changes in the Wisconsin agricultural sector, an alternative measure of economic activity and overall performance is Gross Domestic Product (GDP). Examining long-term trends (1963 to 2022) in Wisconsin, the real GDP (adjusted to 2022 dollars, thereby removing the effects of inflation) of the overall economy grew by 216.8%, while on-farm GDP grew by 33.7% and food processing grew by 80.2% (Figure 1). By comparison, the overall U.S. economy grew by 332.1% over the 1963 to 2022 period, on-farm real GDP grew by 23.1% and food processing grew by 47.4%. Thus, relative to the U.S., the Wisconsin economy grew more modestly, but both farm and food processing GDP grew relatively more. This latter result points to the relative importance of agriculture (both farming and food processing) to the Wisconsin economy.

Trends can provide valuable insights into the growth and decline of the agricultural sector. Figure 1 shows that Wisconsin's economy (all industries) grew little throughout the 1980s, but then entered a period of strong growth in the 1990s through today. Looking at Wisconsin farming, the impact of the Farm Crisis of the early to middle 1980s is clear. Starting in 1979, on-farm Gross Domestic Product steadily declined until 2000, and on-farm GDP flattened and stabilized. In recent years, higher commodity prices in 2021 and 2022 led on-farm GDP to increase by 79.8%. Wisconsin was not unique in this increase as the U.S. farming sector experienced a 66.4% increase and states in the Great Lake region experienced a 153.3% increase. The USDA Economic Research Service (February 7, 2024) suggests however that, "[f]arm sector income is forecast to continue to fall in 2024 after reaching record highs in 2022," and thus, it is unlikely that this recent growth rate in on-farm GDP will persist.

Figure 1 Wisconsin Gross Domestic Product Growth Index (in 2022 dollars)

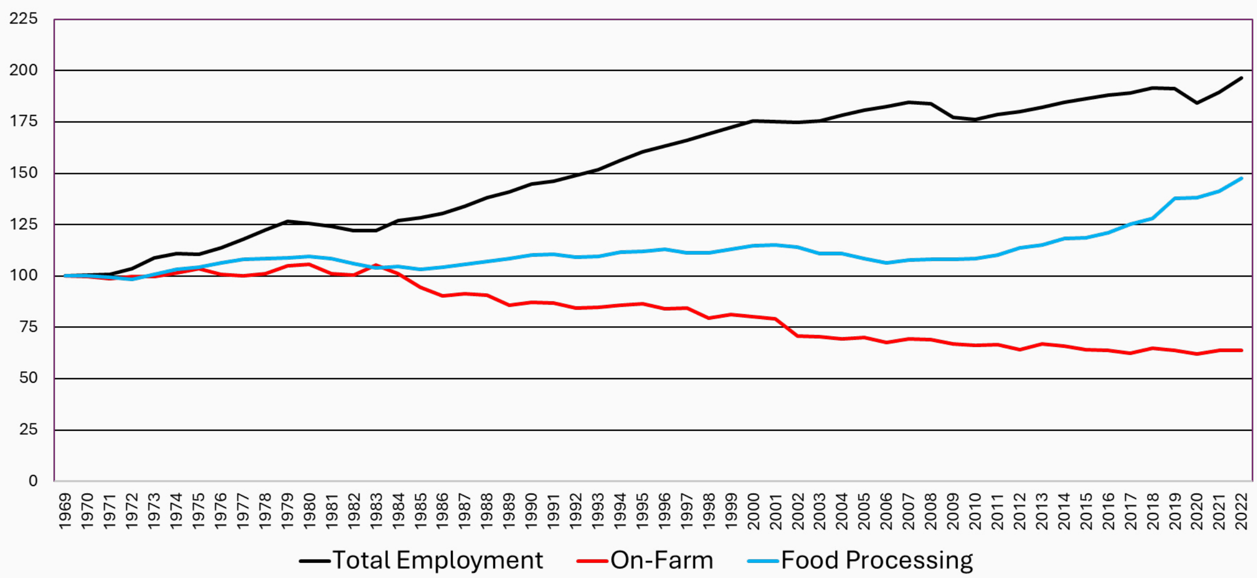


Source: BEA-REIS, calculations by the authors.

Food processing GDP showed strong growth relative to the nation and the Great Lakes region, but the long period between about 1980 and 2008 saw very little meaningful growth in food processing GDP.[1] Starting in 2009, Wisconsin's food processing GDP began to grow steadily. Most of the growth in Wisconsin food processing occurred in the 1970s and since 2009 with the latter period dominating. This growth in food processing GDP over the past 10-12 years complemented the growth in the number of food-processing firms and accompanying employment. In summary, this figure demonstrates that over the last 60 years, an increasing amount of Wisconsin's agricultural GDP occurred off-farm in the value-added stages of food production.

If we examine trends in employment, we see similar patterns as we saw in Gross Domestic Product (Figure 2). While the GDP data began in 1963, the employment data began in 1969 and goes through 2022. Total employment in Wisconsin grew by 96.5% over the period (U.S. total employment increased by 133.3% and the Great Lake States experienced a 64.3% increase), again with clear evidence of economic recessions. On-farm employment, however, declined by 36.3% (U.S. farm employment declined 21.1 % over the same period and farm employment declined 48.8% in the Great Lake States). Note that on-farm employment in Wisconsin was relatively stable from 1969 to 1983 before a period of sustained decline began. This decline in farm employment reflects the decline in the number of farms. Employment in the Wisconsin food processing industry remained relatively flat until about 2010, when it noticeably increased. Over the entire period, employment in food processing in Wisconsin increased by 47.5% (U.S. food processing employment increased by 13.0% over the same period, while food processing employment in the Great Lake States declined by 1.9%), and much of this growth occurred since 2010.

Figure 2 Wisconsin Employment Growth Index

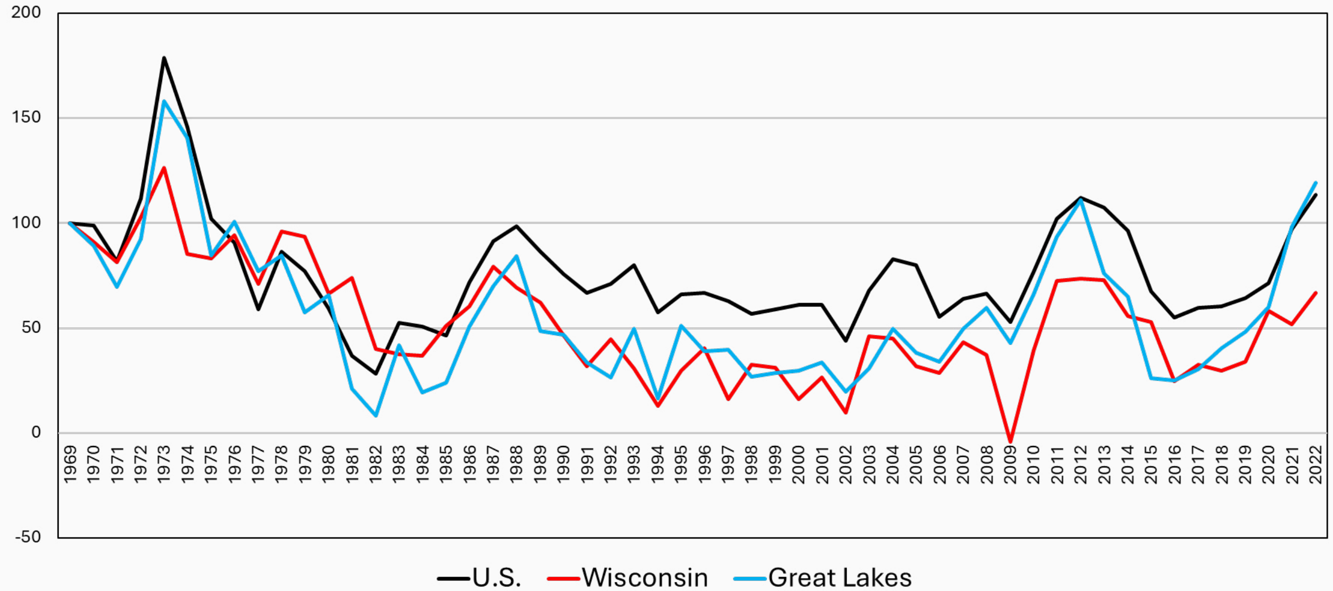


Source: BEA-REIS, calculations by the authors.

1 See Appendix A for figures detailing the Wisconsin, U.S., and Great Lake States comparisons.

Because of tax filing requirements of farm enterprises, specifically Schedule F (Form 1040), we can more closely track the financial health of farms. Here we track Realized Net Farm Income (revenues-expenses) (Figure 3), Farm Proprietor's Income (Figure 4), and Farm Earnings (Figure 5), and adjust all data to 2022 price levels (effects of inflation are removed). For Wisconsin, most farms, nearly nine out of ten, are structured as some form of proprietorship (family, individual, or partnership), and only 6.3% are organized as corporations. Most farms that are structured as a corporation are family-controlled (88.2%). The remaining 1.8% of farms are organized as trustors or are owned by Tribal farmers among other unique forms. How the farm is structured from a business perspective is important in understanding farm income: For most Wisconsin farms, operators take income in the form of proprietor income only after all expenses have been paid. In other words, net farm income (Figure 3) closely tracks farm proprietor income (Figure 4). Because farm earnings capture all sources of farm income, it is slightly more stable.

Figure 3 Realized Net Farm Income Growth Index (in 2022$)



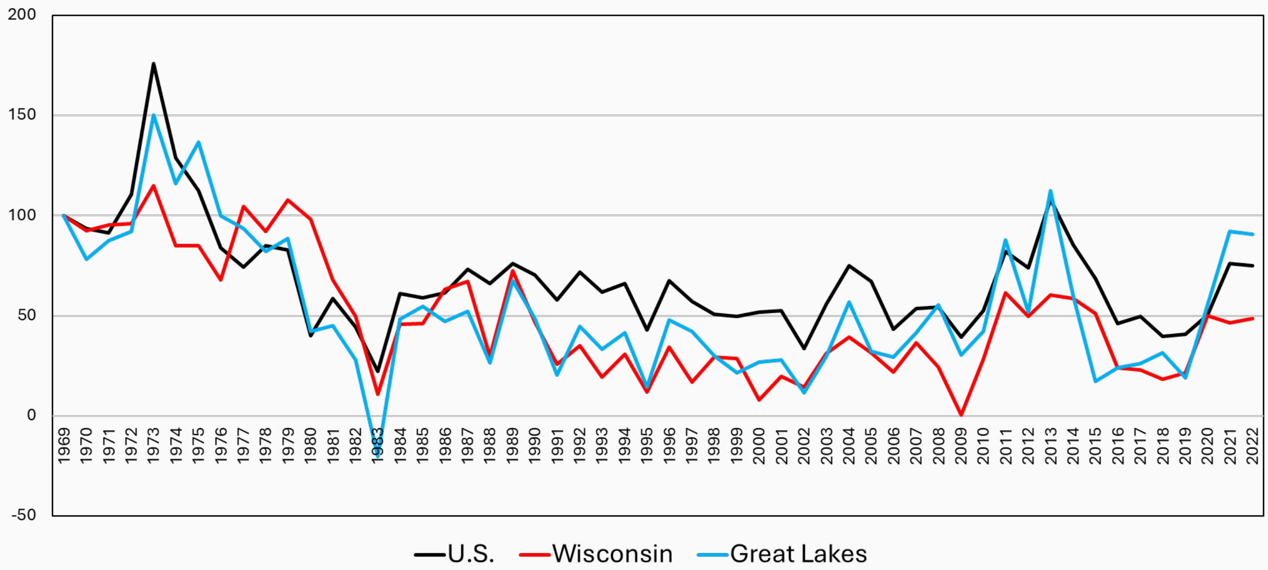
Source: BEA-REIS, calculations by the authors.

2 These data are available from the USDA Economic Research Service (ERS) Farm Income and Wealth Statistics program and the Bureau of Economic Analysis (BEA) Regional Economic Accounts System (REIS). The USDA data is derived from the Agricultural Resource Management Survey (ARMS), while the BEA REIS data primarily utilizes IRS records. Although there are technical differences in definitions and measurements between the two sources, these differences are minimal at the trend analysis level reported here. This study is based on the BEA REIS data.

3 Farm proprietor's income is defined as income that is received by the sole proprietorships and the partnerships that operate farms. Income received from farms organized as corporations are not included.

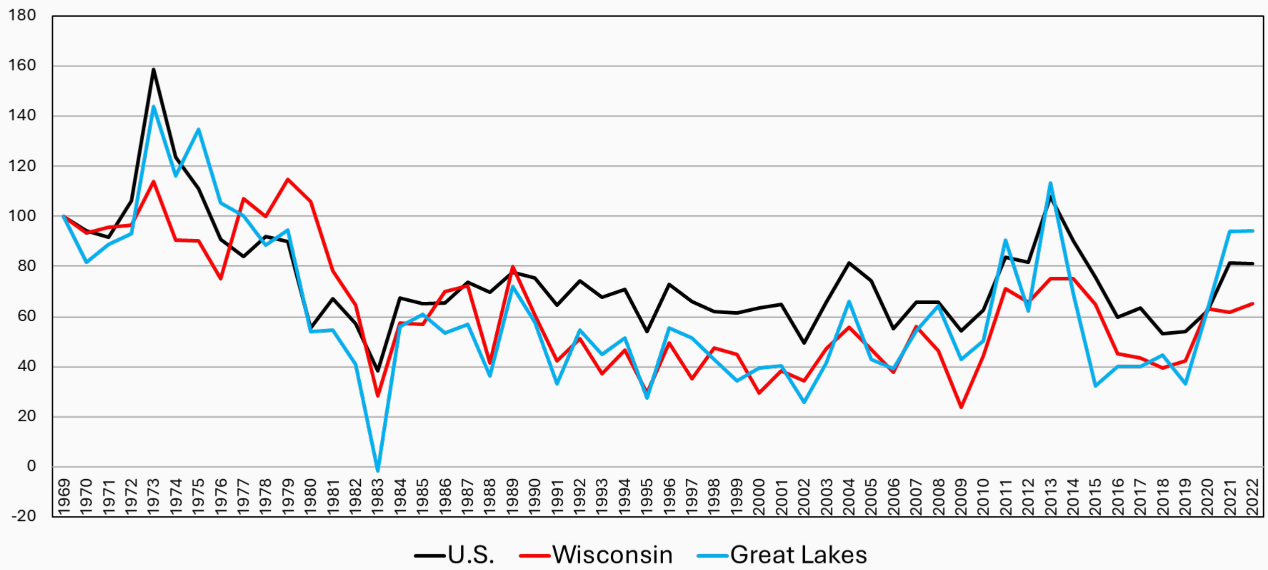
4 Farm Earnings is defined as income from all sources of farm activity including proprietor's income, corporate farm income, farm worker's income, and rental income, among other more minor sources.

Figure 4 Farm Proprietor's Income Growth Index (in 2022$)



Source: BEA-REIS, calculations by the authors.

Figure 5 Farm Earnings Growth Index (in 2023)



Source: BEA-REIS, calculations by the authors.

1 See Appendix A for figures detailing the Wisconsin, U.S., and Great Lake States comparisons.

There are several patterns observed in the farm financial and income data: (1) growth in farm income has been flat for five decades, (2) the inherent instability in farm income is readily apparent, and (3) most "down" years are followed by "up" years. Note that 2022, the year for this contribution analysis, appears to be at the top of a couple of good years. As noted above, the USDA Economic Research Service expects national farm income will continue to fall in 2024 after reaching record highs in 2022. Because of this inherent instability in farm income, farmers are adept at managing risk and planning over successive years. There are two periods of sustained down years, the early 1980s and 2013-2019 Both periods ended with what could be referred to as a "farm crisis". The inability of farmers to recoup losses by rebuilding assets (e.g., cash reserves) and paying down debt, forced farmers into unacceptable financial situations. Because most Wisconsin farmers take their earnings (income flowing to the family/household) from net farm income, successive down years creates an unsustainable fiscal situation for the farm family and accumulating farm debt can overleverage the farm enterprise. The result is farm failures and exits.

One strategy that many Wisconsin farm families (households) have pursued to provide some stability in family finances is off-farm income (e.g., Deller 2022). While off-farm employment has been a tradition for numerous years, primarily as a source of health insurance, the farm family (household) has become increasingly dependent on off-farm income. Using the USDA ARMS (Agricultural Resource Management Survey) data for Wisconsin farms, over the five-year average (2018-2022), 79.3% of farm family income came from off-farm sources. While this share is lower for the largest farms (sales over $1M the average is 15.1%), for the smallest farms, which are the preponderance of farms in Wisconsin (sales under $100,000), the average is 102.5%. This off-farm income provides a buffer for many Wisconsin farms and may cover average losses for the smaller farms. Off-farm income is not considered in the contribution analysis which is the focal point of this study. One policy implication of the growing dependence on off-farm income to sustain more modest-sized Wisconsin farms is to promote greater employment opportunities in nearby communities.

The historical analysis reveals several key takeaways. First, the number of farms and number of people employed on farms in Wisconsin continues to decline. Despite this, however, on-farm GDP has been relatively stable over the long term with periods of volatility in the short term. This is consistent with the notion that fewer large farms produce larger commodity volumes. Second, some of the on-farm contraction is offset by growth in the State's food processing sector. While similar growth has happened nationally, Wisconsin showed extraordinary growth over the period, perhaps because of the strong dairy and processed vegetable industries. Overall, the Wisconsin agricultural economy is dynamic and changing. Increasingly, value-added processes are a source of revenue and employment growth for the Wisconsin agricultural industry, and fewer people are directly involved in on-farm production. Can the sustained growth in specialized food processing create opportunities for Wisconsin farms? If so, how can the industry work strategically to build on those opportunities? We will explore these questions in the next section.

Agricultural Cluster Analysis

The Wisconsin Economic Development Corporation has identified six "key industries" or "economic clusters" that are fundamental to the Wisconsin economy. These industries are bio-health; water technology; advanced manufacturing; forest products; energy, power, and controls; and food and beverage industries. Our intent in this section is to explore the changing nature of the food and beverage industry, which for our purposes, includes on-farm activities and food and beverage processing. Specifically, using IMPLAN-sourced employment data for 2001 and 2022 (consistent with the contribution analysis), we track the relative strength of Wisconsin's individual on-farm and food processing sectors relative to the nation.

The specific framework we employ is commonly used to identify what is widely referred to as "economic clusters". As noted in Deller (2014), Forward Wisconsin, which is embedded in the Wisconsin Economic Development Corporation, defined economic clusters in 2003 as:

> . . .geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field. Clusters develop because they increase the productivity with which companies can compete in an increasingly more competitive global market, and they are the source of jobs, income, and export growth. The philosophy behind clusters is that large and small companies in a similar industry achieve more by working together than they would individually [emphasis added]. Clusters give businesses an advantage by providing access to more suppliers and customized support services, skilled and experienced labor pools, and knowledge transfer through informal social exchanges. In other words, clusters enhance competitiveness.

Consider the observation above noting that growth in food processing in Wisconsin could create unique opportunities for Wisconsin farmers with the challenge of the industry working in partnership to leverage those opportunities. An effective economic cluster, where "companies in a similar industry achieve more by working together", is an industrial setting where such leveraging is possible. The question is how the public sector (e.g., state government, the University of Wisconsin, the Wisconsin Technical College System, along with local and regional groups) can help leverage those networks underpinning the economic cluster.

While there are numerous methods to identify economic clusters, location quotients (LQ) have been widely used across Wisconsin. The location quotient (LQ) is an indicator of the self-sufficiency, or relative strength, of a particular industry.[5] The LQ is computed as:

$$LQ_i = \frac{\textit{Percent of local economic activity in sector i}}{\textit{Percent of national economic activity in sector i}}$$

How close to one is close enough?

While the Location Quotient has a definitive threshold of one, there remains room for interpretation. Some have suggested that when interpreting Location Quotient more reasonable thresholds might be above 1.1 and below 0.9 and Location Quotients between those two ranges are closed enough to 1.0 to be acceptable.

The proportion of national economic activity in sector i located in the region (state or community) measures the region's production of product i, assuming equal labor productivity. The proportion of national economic activity in the region is a proxy for local consumption, assuming equal consumption per worker. The difference between local production and consumption is an estimate of production for export (i.e. production > consumption).

5 The key underlying assumptions of the location quotient approach is that regional production technology is identical to national production technology (i.e. equal labor productivity) and that local tastes and preferences are identical to national tastes and preferences (i.e. equal consumption per worker). Assuming the national economy is self-sufficient (i.e., no international trade), the comparison between the community and the national benchmark gives an indication of specialization or self-sufficiency.

As constructed, the LQ is centered on a value of one, where an LQ equal to one means the region has the same proportion of economic activity in sector i as the nation. This indicates that local production of a specific good or service exactly meets local consumption in that region. If the location quotient is less than one (1), the region is not producing enough to meet local needs. If the location quotient is greater than one, the region has a larger proportion of its economy in sector i than does the rest of the nation.

Consider a simple mapping of the level and change of the LQ as outlined in Figure 6. There are four potential combinations.

- First, if the industry has a LQ less than one and is decreasing over time, this industry is considered a "weakness and declining" industry, and generally, should not be considered a potential cluster.
- Second, if the LQ is less than one but increasing, the industry can be considered a "weakness and growing", and it may be a possible industry of focus for economic development.
- Third, if the LQ is greater than one but is declining over time, the industry is considered a "strength and declining." Industries in this category might be considered at risk and deserving of special consideration to understand why a strong industry (i.e. LQ>1) is weakening (i.e. Δ LQ<0). In particular, does the decline of these industries present a potential risk to the regional economy?
- Fourth, if the LQ is greater than one and growing over time, it is considered a "strength and growing." Industries in this category might be considered potential clusters for economic growth and development. These industries have self-identified the region as having a comparative advantage over other regions and may have further growth potential.

Figure 6 Possible Industry Combinations

LQ 2001 - 2022

Weakness and growing, potential opportunity	**Strength and growing, potential cluster**
Weakness and declining	**Strength and declining, potential threat**

On-Farm Cluster Analysis

Using employment data from IMPLAN for 2001 and 2022, we calculate the Location Quotients and summarize the results in Table 1 and Figures 7a and 7b for on-farm industries. Focusing first on on-farm industries that are classified as potential economic clusters, it becomes clear that dairy farming and milk production are strengths (LQ=7.41) and are growing (an increase of 3.38), and at the same time, they account for 53.1% of all on-farm employment. Clearly, dairy farming is a viable economic cluster. But there are also several other on-farm sectors that fall into the potential cluster quadrant of Figure 6, including fur-bearing animal and rabbit production, goat farming, oilseed (other than soybean) farming, aquaculture, and vegetable (and melon) farming among a few others. Consider fur-bearing animal and rabbit production, where the location quotient is a remarkably high 20.12 and grew by 8.40 from 2001. By all measures, this is a remarkably strong cluster, and it is widely known that Wisconsin dominates the fur-for-clothing market in the U.S. Having said that, its share of total on-farm employment is only 0.8%. A similar observation could be made for goat farming. It had a location quotient of 6.61 in 2022, and it accounted for only 0.3% of all on-farm employment in 2022.[6] The policy question is whether these smaller on-farm sectors are of sufficient size or scale to warrant special consideration.

When is the share of employment sufficient large?

A key element of any clusteranalysis is assessing when therelative size of an industry issufficiently large to warrant furtherconsideration. Unfortunately, thereis no definitive threshold as share ofemployment will grow smaller asthe level of industry specificity becomes more refined. Clearly asone explores more detailedindustrial groups the relative sizeswill become smaller. Consequently,the results of such cluster analysesare meant to be indicative ratherthan conclusive

Vegetable (and melon) farming, corn farming, and support activities for animal production are three other economic clusters in the state. Consider the latter, support activities for animal production, which accounts for 7.5% of all on-farm employment, and a location quotient of 3.58 in 2022, which increased by 1.22 from 2001. In 2022, there were 135 Wisconsin businesses in this category, each with an average of just over 15 employees. This sector includes businesses that provide artificial insemination services for livestock, livestock breeding services more generally, poultry house cleaning, and hoof trimming, among others. Given the importance of livestock-based farm activities across Wisconsin, the relative importance of this sector perhaps matches expectations. From an economic growth and development perspective, it is intuitive that fostering strategies and policies aimed at enhancing the on-farm economy should include businesses that provide support activities for livestock farming.

6 The key underlying assumptions of the location quotient approach is that regional production technology is identical to national production technology (i.e. equal labor productivity) and that local tastes and preferences are identical to national tastes and preferences (i.e. equal consumption per worker). Assuming the national economy is self-sufficient (i.e., no international trade), the comparison between the community and the national benchmark gives an indication of specialization or self-sufficiency.

Given that parts of Wisconsin are contained within the Corn Belt, it is no surprise that corn farming is considered an economic cluster within the Wisconsin on-farm industry.[7] The location quotient for corn farming is 2.23 in 2022 (a modest increase of 0.12 from 2001) and accounts for 2.8% of all on-farm employment. Finally, given the scale of operations in Wisconsin's Central Sands region, vegetable (and melon) production is a potential cluster in the on-farm sector. Still, unlike some of the other on-farm sectors in the cluster quadrant of Figure 6, the size of the 2022 location quotient is only modestly above one.

There are a handful of on-farm operations that have location quotients less than one in 2022, indicating that the sectors are not necessarily strengths, but the location quotient has increased from its 2001 value. For example, the value of the location quotient for hay farming was 0.45 in 2022, an increase of 0.42 from 2001 values. The level of employment, however, is relatively modest, accounting for 0.3% of total on-farm employment. Other sectors in this "potential opportunity" quadrant of Figure 6, including, poultry hatcheries, support activities for forestry, and horses and other equine farms, show similar signs of growing importance through increases in the location quotient, but account for small shares of on-farm employment. Other on-farm sectors warrant further consideration, such as sheep farming and noncitrus fruit and tree nut farming. Sheep farming, much like goat farming, did not have a statistical presence in Wisconsin in 2001 but had an employment presence in 2022 (0.1%). As such, the location quotient went from zero in 2001 to a positive value in 2022 (0.72). The same could be said about tobacco farming, but the size of the location quotient and employment share for tobacco farming suggest that it is a minor crop for Wisconsin. Noncitrus fruit and tree nut farming, which includes cranberries and a more modest hazelnut industry, has a location quotient of 0.41, which increased by 0.09 from 2001, accounts for 4.4% of on-farm employment, and places it sixth highest out of the 35 on-farm sectors included in this cluster analysis. Given the dominance of the Wisconsin cranberry farm production relative to the U.S., one would expect cranberry production to be classified as a potential cluster. The way IMPLAN aggregates its industrial sectors, unfortunately, does not allow for a more refined analysis.

A handful of on-farm sectors appear to be shrinking relative to the U.S., measured by a declining location quotient. Only one sector is classified as a "threat" by being in the lower right-hand quadrant of Figure 6, or the current location quotient was greater than one but declined over the 2001-2022 period. The hunting and trapping sector experienced a sizable decline (-12.90) but this sector accounted for only 0.2% of on-farm employment. Perhaps of more concern is the decline in the beef cattle farming sector, which went from a location quotient of 2.33 in 2001 to 0.58 in 2022, a decline of 1.75. Given that beef farming accounts for 2.2% of on-farm employment in 2022 (ranked 9 out of the 35 on-farm sectors examined), this could be reclassified from "neither opportunity nor threat" to "potential threat". Nursery and floricultural production is a relatively large employment sector and experienced a decline in its location quotient. In 2022, this sector accounted for 6.5% of on-farm employment, placing it behind only dairy farms (53.1%) and support activities for animal production (7.5%). While the location quotient was 0.73 in 2022, the decline from 2001 to 2022 of 0.03 indicates that this part of the Wisconsin on-farm economy may warrant special attention.

While dairy farming dominates the Wisconsin on-farm economy, one of the important takeaways from this cluster analysis is the diversity of agriculture across the state. Using USDA data, the Wisconsin Department of Agriculture, Trade, and Consumer Protection notes that in 2022 Wisconsin ranked as the top producer of corn for silage, cranberries, snap beans, milk goats, and mink pelts; second in forage and dairy cows; and third in carrots, green peas, sweet corn, and potatoes (Wisconsin 2023

7 The data used in this analysis is not sufficiently detailed to distinguish between sweet corn for humanconsumption and field corn often used for animal feed

Agricultural Statistics). The cluster analysis provided in Table 1 and Figures 7a and 7b reaffirms the conclusions of the statewide statistics and national rankings: The Wisconsin on-farm agricultural sector is exceptionally diversified which presents unique opportunities and challenges.

Because of the diversity, Wisconsin on-farm agriculture is not as exposed to volatility in any one sector, except perhaps for dairy milk production. Rather, the risk is spread across agricultural products, and a shock to one sector may not be as devastating to the entire State's economy. The farm crisis of the 70s and 80s, for example, was dampened in Wisconsin relative to less-diversified corn-belt states. In addition, having a foundation of diverse products and the infrastructure to support them allows for opportunistic expansion if one sector experiences market growth. Take for example a positive demand shock for American ginseng. The capability and knowledge already exist in Wisconsin, and Wisconsin would stand to be almost exclusive beneficiaries of such a shock.

The challenge of this, however, centers on the unique needs of various on-farm sectors. The needs for goat and sheep farming, which may overlap some elements of the dairy and beef sectors, are very different than vegetable or fruit farming. Developing a portfolio of policies that are custom to such a variety of farms can be challenging. Because so many Wisconsin farms are relatively modest in scale, the needs for business management training and support, for example, are similar regardless of the commodity or product being produced. As noted in the definition of economic clusters, a key element of a dynamic cluster is "companies in a similar industry achieve more by working together than they would individually". Here, public institutions such as those referenced above and organizations such as the Wisconsin Cranberry Growers Association, Wisconsin Beef Council, or the Wisconsin Corn Growers Association can provide an institutional mechanism for producers to network and exchange information and ideas. But the scale or size of the sector can be a limitation: Is there a sufficient number or scale of farmers to build deep networks? Here dairy farming is sufficiently large that groups such as Dairy Farmers of Wisconsin and Professional Dairy Producers of Wisconsin have critical mass. In addition, the degree of networking across different commodity (product) groups can be limited. Clearly, the opportunities associated with such a diversified on-farm economy outweigh the challenges.

Table 1 Wisconsin On-Farm Cluster Analysis

	LQ 2022	Change LQ 2001-2022	Share of On Farm Employment (%)
Potential Cluster			
Fur-Bearing Animal and Rabbit Production	20.115	8.403	0.78
Dairy Cattle and Milk Production	7.415	3.381	53.13
Goat Farming	6.608	6.608	0.27
Support Activities for Animal Production	3.576	1.221	7.49
Other Poultry Production	3.384	2.128	0.40
Oilseed (except Soybean) Farming	2.473	2.473	0.04
Corn Farming	2.227	0.120	2.77
Dry Pea and Bean Farming	1.683	1.249	0.05
Aquaculture	1.167	0.852	0.63
Vegetable and Melon Farming	1.038	0.033	5.84
Potential Threat			
Hunting and Trapping	1.392	-12.895	0.20
Potential Opportunity			
Logging	0.767	0.009	2.39
Apiculture	0.760	0.611	0.20
Sheep Farming	0.726	0.726	0.05
Other Grain Farming	0.680	0.514	1.01
All Other Crop Farming	0.519	0.231	1.56
Hog and Pig Farming	0.471	0.146	0.93
Hay Farming	0.450	0.415	0.28
Noncitrus Fruit and Tree Nut Farming	0.413	0.086	4.41
Horses and Other Equine Production	0.376	0.156	0.15
Support Activities for Forestry	0.296	0.061	0.44
Poultry Hatcheries	0.264	0.180	0.17
Support Activities for Crop Production	0.229	0.118	5.25
Tobacco Farming	0.173	0.173	0.02
Timber Tract Operations	0.062	0.019	0.03
Broilers and Other Meat Type Chicken Production	0.033	0.033	0.02
Neither Opportunity or Threat			
All Other Animal Production	0.998	-1.494	0.77
Chicken Egg Production	0.856	-0.010	1.20
Nursery and Floriculture Production	0.734	-0.033	6.55
Beef Cattle Ranching and Farming, including Feedlots	0.581	-1.752	2.19
Soybean Farming	0.221	-0.097	0.08
Food Crops Grown Under Cover	0.197	-0.019	0.64
Fishing	0.188	-0.167	0.08
Turkey Production	0.029	-0.125	0.01
Forest Nurseries and Gathering of Forest Products	0.000	-0.242	0.00

Figure 7a Wisconsin Food Processing Cluster Analysis

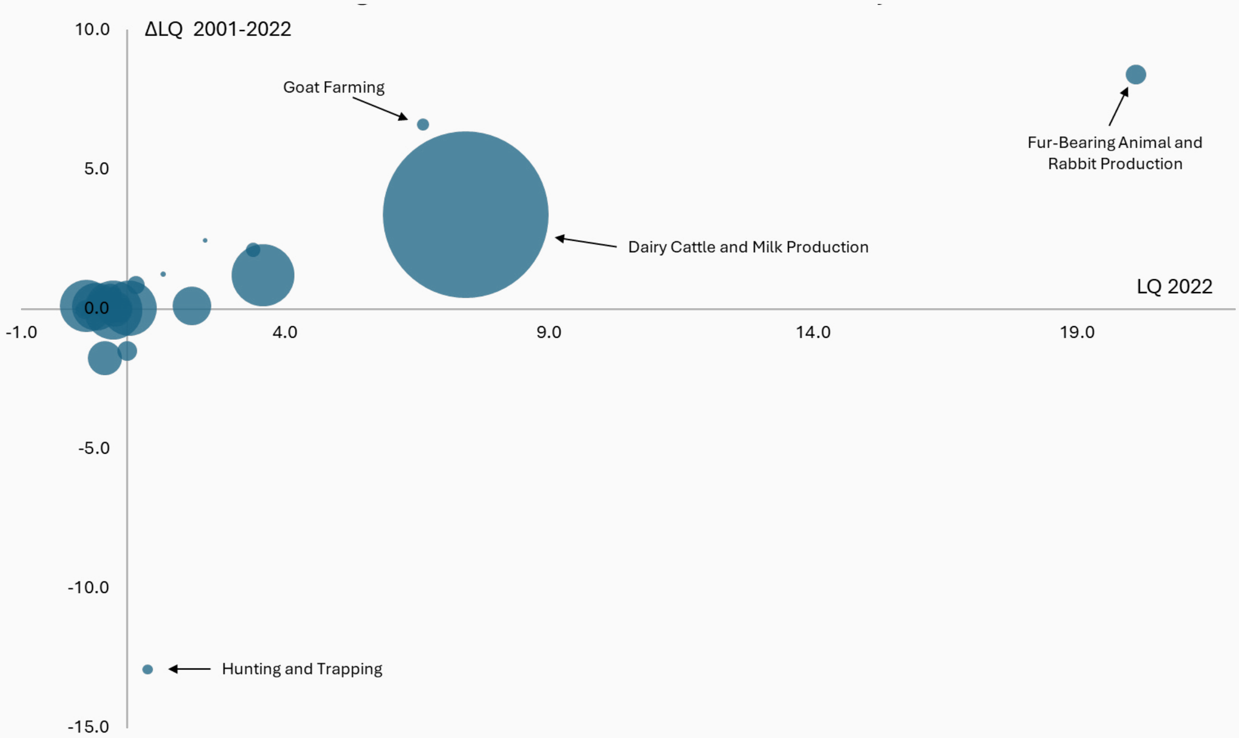
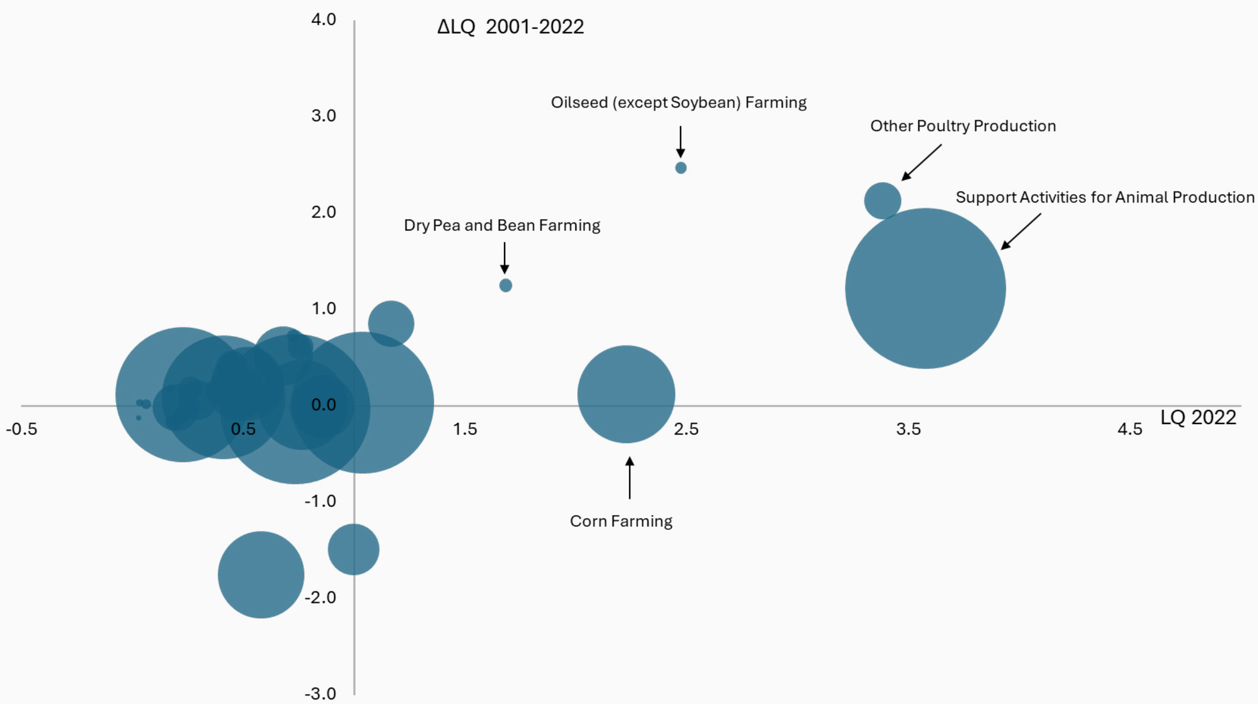


Figure 7b Wisconsin Food Processing Cluster Analysis



Food Processing Cluster Analysis

As with the on-farm cluster analysis, using employment data from IMPLAN for 2001 and 2022, we calculated the location quotients and summarize the results in Table 2 and Figures 8a and 8b for food processing industries. Here, 24 individual sectors make up food processing, and ten are identified as strengths and are growing (upper right-hand quadrant of Figure 6) and are classified as potential economic clusters. Much like how dairy farming "stood out" as the largest potential cluster in the on-farm analysis, dairy product (except frozen) manufacturing dominates Wisconsin's food processing sector. While this sector includes a handful of sub-sectors, such as fluid milk processing and butter, the overall sector is dominated by cheese production. With a location quotient of 10.33 in 2022, an increase of 3.38 over 2001 levels, this sector accounted for almost one-third (31.8%) of all employment within food processing. This result on dairy processing aligns with expectations. In 2022, Wisconsin was ranked as the top-producing state for American, Cheddar, and Italian cheeses and second for Mozzarella cheese, which accounted for 25.0% of all cheese produced in the U.S. (Wisconsin 2023 Agricultural Statistics). Indeed, almost 90% of dairy milk production in Wisconsin goes into the production of cheese. There were other components of the Wisconsin food processing industry beyond dairy processing (predominately cheese) that were strengths and growing (upper righthand quadrant of Figure 6) including frozen food manufacturing, animal food production, seasoning and dressing manufacturing, and a handful of other smaller (in terms of employment) food processing sectors.

Unlike on-farm activity, where only one relatively small sector (hunting and trapping) was classified as a potential threat because of the declining value of the location quotient, six food processing sectors were classified as posing a potential threat. For example, flour milling and malt manufacturing had a location quotient of 1.32 in 2022, which was a decline of 0.22 from its levels in 2001. But this sector accounted for only 0.6% of the total food processing sector. Most of the food processing sectors identified here experienced modest declines in their location quotients over the study period. For example, nonchocolate confectionery manufacturing experienced a decline of only 0.08. Breweries, which accounted for 4.5% of all food processing employment in 2022, experienced a decline in their location quotient of 0.18. While there was a significant growth in the number of craft and microbreweries across Wisconsin over the 2001 to 2022 period, some of the larger breweries experienced restructuring. This analysis is not sufficiently detailed to suggest that this restructuring may threaten the whole of the Wisconsin brewery industry. There was also a modest decline in the relative strength (i.e., a declining location quotient) in the animal slaughtering and processing sector. While a decline of only 0.08 may appear insignificant, this sector accounted for 19.7% of all food processing employment in Wisconsin. It is not clear if the noticeable decline in the beef cattle farming sector noted in the previous section was linked to the modest decline in animal slaughtering and processing. As with the brewery industry, perhaps additional analysis of this sector is warranted beyond what is presented here.

One food processing sector, fruit and vegetable canning (pickling/drying), has experienced difficulties for several years. Most of the vegetable production in Wisconsin goes directly into canning and freezing processes. Considering it has a relatively large location quotient (3.28) and a high share (6.2%) of total food processing employment, the decline in the location quotient of 1.36 is a potential concern. Multiple reasons might explain why this sector has experienced pressures (e.g. international competition, changes in consumer demands, and the costs of aluminum for the cans), and why it poses a potential threat to the Wisconsin food processing industry.

There are signs of some pressure alleviation through the growth in frozen food manufacturing (identified as a potential cluster), but frozen food manufacturing encompasses more than just vegetable processing.

The cluster analysis of Wisconsin's food processing sector using employment data from 2001 to 2022 suggests that six subsectors are potential opportunities (upper left-hand quadrant of Figure 6). While each of these, except for soft drink (and ice) manufacturing accounts for less than one percent of total food processing employment, two subsectors warrant further discussion: Distilleries and wineries. While distilleries are a small industry relative to the rest of the Wisconsin food processing industry (0.3% of food processing employment), the location quotient of 0.59 was a marked increase over the 2001 level. Indeed, based on the IMPLAN employment data, there were no distilleries with statistically significant employment in 2001. In essence, this is a new industry within Wisconsin. The second industry, wineries, has also shown growth. While there have been wineries in Wisconsin for decades, such as in Door County, there was noticeable growth over the study period. In 2022, the location quotient for Wisconsin wineries was 0.56, an increase of 0.32 over 2001 levels, and the industry accounted for 1% of Wisconsin food processing employment. The growth in these two sectors can be attributed to changing consumer tastes and preferences, particularly the continued growth in preferences for local foods. In addition, local breweries, artisan cheese manufacturers, wineries, and distilleries have formed tourism-focused economic clusters. By forming partnerships these food-based industries have formed viable economic clusters akin to the food and wine cluster of Napa Valley California.

As with the on-farm activity, the food processing industry in Wisconsin is relatively diversified. While dairy processing (i.e., cheese) and animal processing (slaughtering) accounted for more than half (51.5%) of employment in the food processing sector, food processing in Wisconsin has a wealth of diversity including breweries, distilleries, and wineries. This diversity is important because it helps protect the Wisconsin food processing industry from outsized shocks to any one part of the industry portfolio. Continued pressure in the vegetable canning industry, however, is a potential cause for concern.

Table 2 Wisconsin Food Processing Cluster Analysis

	LQ 2022	Change LQ 2001-2022	Share of Food Processing Employment (%)
Potential Cluster			
Dairy Product (except Frozen) Manufacturing	10.33	3.38	31.83
Seasoning and Dressing Manufacturing	3.24	0.77	3.54
Frozen Food Manufacturing	3.22	0.28	6.93
Animal Food Manufacturing	2.33	0.68	3.78
Chocolate and Confectionery Manufacturing	2.32	1.01	2.21
All Other Food Manufacturing	2.01	0.03	4.72
Coffee and Tea Manufacturing	1.81	1.27	1.1
Flavoring Syrup and Concentrate Manufacturing	1.4	0.8	0.29
Bread and Bakery Product Manufacturing	1.2	0.06	6.75
Cookie, Cracker, and Pasta Manufacturing	1.17	0.16	1.57
Potential Threat			
Fruit and Vegetable Canning, Pickling, and Drying	3.28	-1.36	6.16
Breweries	1.86	-0.18	4.46
Animal Slaughtering and Processing	1.63	-0.08	19.67
Nonchocolate Confectionery Manufacturing	1.62	-0.08	0.89
Flour Milling and Malt Manufacturing	1.32	-0.22	0.64
Snack Food Manufacturing	1.25	-0.15	1.8
Potential Opportunity			
Soft Drink and Ice Manufacturing	0.62	0.06	1.48
Distilleries	0.59	0.59	0.34
Wineries	0.56	0.32	0.97
Starch and Vegetable Fats and Oils Manufacturing	0.46	0.45	0.31
Breakfast Cereal Manufacturing	0.25	0.25	0.07
Tortilla Manufacturing	0.13	0.07	0.06
Neither Threat or Opportunity			
Ice Cream and Frozen Dessert Manufacturing	0.77	-0.34	0.43
Seafood Product Preparation and Packaging	0.04	-0.01	0.03

Figure 8a Wisconsin Food Processing Cluster Analysis

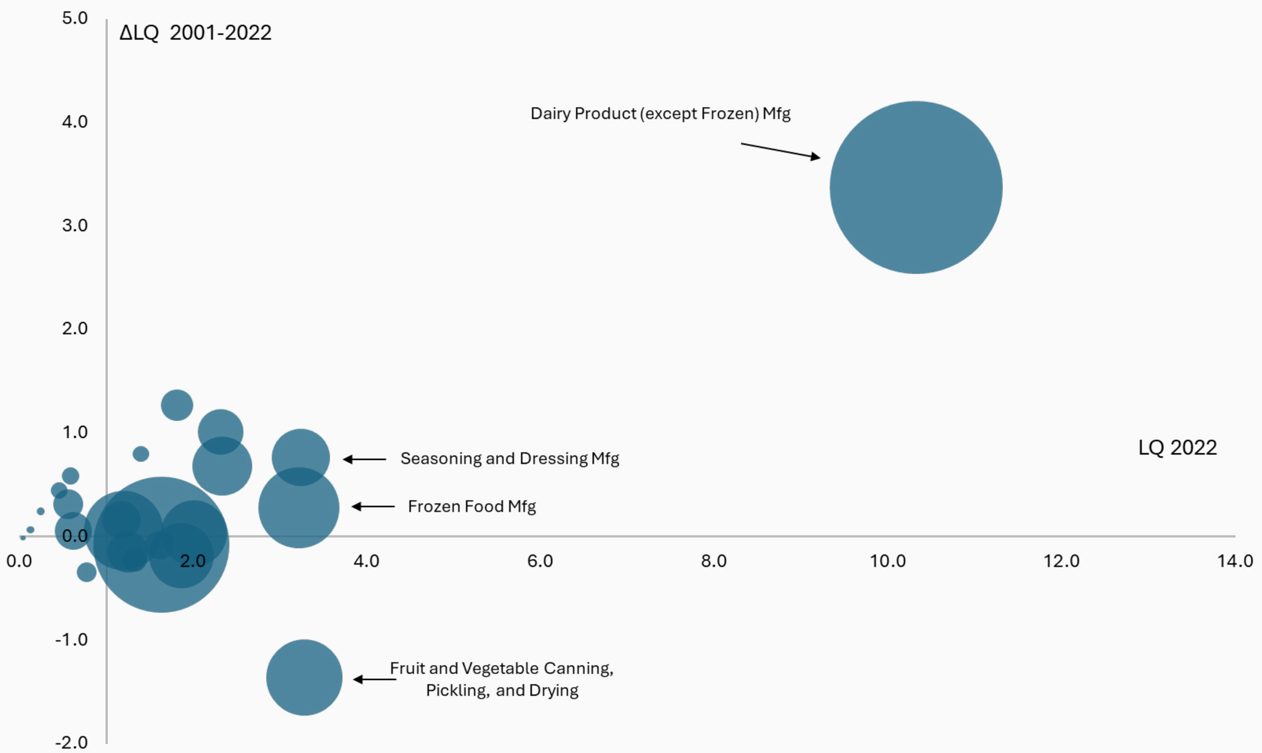
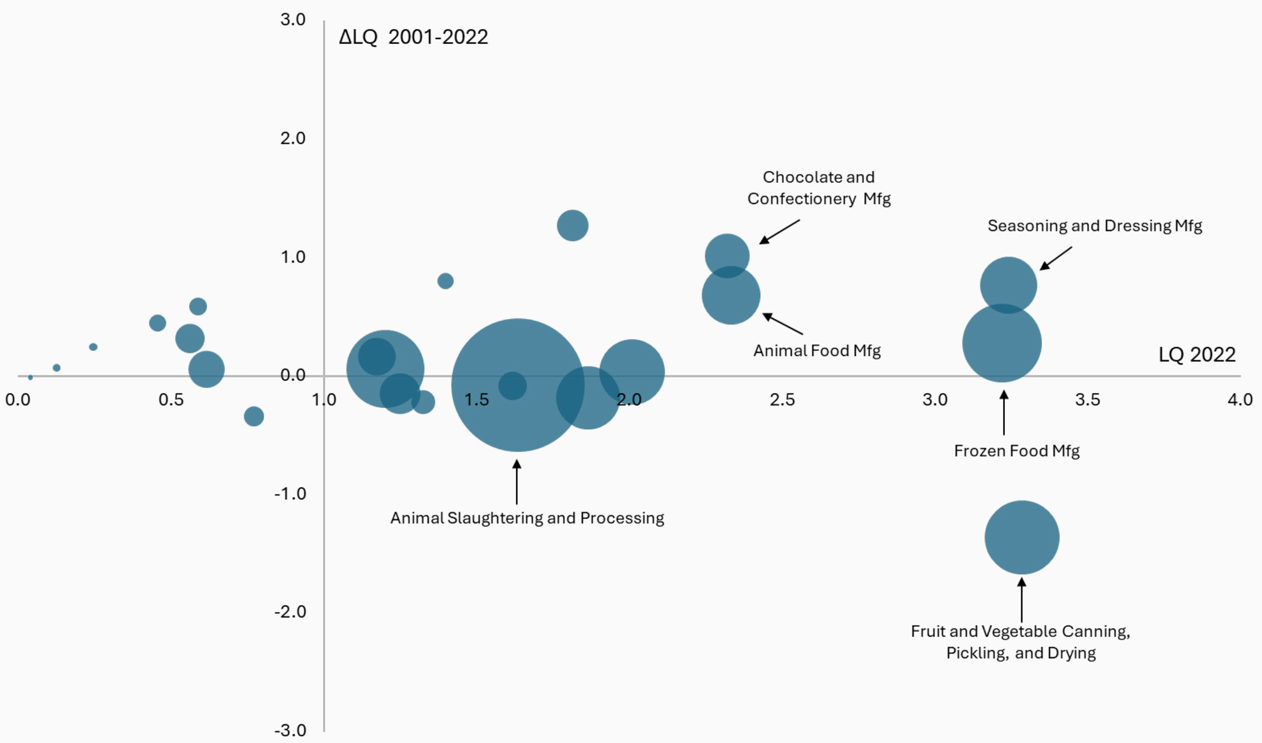


Figure 8b Wisconsin Food Processing Cluster Analysis



A Simple Review of Methods and Definitions of Terms

In each of the previous Contribution of Agriculture to the Wisconsin Economy studies, we relied on regional input-output economic models of Wisconsin using the IMPLAN Modeling System. As discussed in more detail in Appendix 2, input-output analyses are an advantageous tool to track how small changes in one part of the economy resonate throughout the entire economy. For example, the expansion of dairy farms in the local economy introduces new or additional levels of spending in the local economy. This new spending causes a ripple, or multiplier effect, throughout the economy. Using input-output analysis, we can track and measure this ripple effect.

Continuing with the dairy farms example, the impact of an expansion of dairy farms is composed of three parts: direct, indirect, and induced. The direct effect captures the event that caused the initial change in the economy. For example, an entry of a new dairy or an existing dairy operation expanding. The dairy farm contributes directly to the local economy by selling farm products, paying employees' wages, and generating proprietor income for the farmer. The new dairy farm has two types of expenditures that can illustrate the second two parts of the impact or multiplier. The first is business-to-business transactions, such as the purchase of feed from other farms or feed suppliers, fertilizer, seed, chemicals, veterinary services, trucking services to haul milk and livestock, electric and other utilities, insurance, interest and other financial services, land rent, farm and equipment repairs and maintenance, and many others. These business-to-business transactions are captured in the model through the indirect effect. In this situation, a grain farmer uses the proceeds from feed sales to dairy farmers to pay his or her own farm's operating expenses, make investments, or buy new equipment.

The second type of expenditure dairy farms introduce into the local economy is wages and salaries paid to employees and to the farmers themselves. Spending this income in the local economy is captured by the induced effect. Dairy farmers and their employees spend their income at local grocery stores, movie theaters, restaurants, and other retail outlets. The theater owner, then, uses part of the dairy farmer's ticket sales to pay theater employees, and the cycle continues.

The combination of the direct, indirect, and induced effects tells us any industry's complete impact on or contribution to the whole economy. By looking at the indirect and induced impacts, we can gain insights into how an industry of interest is connected or integrated into the local economy. Industries that are labor-intensive and offer high wages tend to have larger induced effects on the local economy. Industries that are more capital-intensive or offer lower wages tend to have larger indirect effects. We can also gain additional insights into the make-up of the local economy by examining the relative size of the multiplier effects. Smaller economies tend to have smaller multiplier or ripple effects than larger economies. This is because the "leakages" out of the local economy occur faster in smaller economies. Larger economies have greater opportunities to keep those dollars within the local economy for a longer period (i.e. larger multiplier effects). Some smaller, rural communities pursuing tourism development have used multiplier analysis to learn that simply bringing more tourists to the community is insufficient. The communities must also have a place for those tourists to spend their money.

For this study, we use four measures of economic activity: employment, labor income, total income, and industrial revenues/sales. Employment is simply the number of jobs and is not a full-time equivalent. For example, two part-time jobs created in any sector are considered two jobs, while one full-time job in any sector is considered one job.

Labor income is the return to labor and includes wages, salaries, and proprietor income. As noted in the trend analysis above, most labor income comes through wages and salaries. In agriculture, though, many farmers take income via proprietor income. Proprietor income is the farmer's return on labor input into the farm. Total income includes labor income and other sources of income such as dividends, interest, and rental payments as well as transfer payments such as social security payments. For our purposes, total income is akin to gross domestic product, explored in the trend analysis. Industry sales or revenues are simply total revenues flowing to an industry.

Consider a dairy farmer who has $1 million in sales/revenues and two hired workers who are each paid $25,000. The farmer has structured the business to draw a $50,000 salary. Also, suppose that the farm turns a $10,000 "profit" that the farmer takes as proprietor income. In this example, industry sales/revenue is $1 million, employment is three (two workers plus the farmer), and labor income is $110,000. Suppose that this farmer has crop acreage that is rented to a neighboring farmer for which the farmer receives $5,000 in rental income. Here, total income would be $115,000.

Economic Contribution Analysis

In this study, we update previous estimates of the contribution of agriculture to the Wisconsin economy (Deller, 2004, 2014, 2017; Deller and Williams 2009, 2011). In addition to providing state-wide estimates, we provide estimated contributions for the nine sub-regions within Wisconsin which correspond to the National Agricultural Statistics Service's (NASS) grouping of counties. The results of the state-wide analysis are provided in Tables 3a and 3b. In 2022, all agricultural activities, both on-farm and food processing, contributed $116.28 billion to the Wisconsin economy using industrial revenues (or sales) as the economic metric. This represented an increase of $11.5 billion over the 2017 estimates, or about an 11.0% increase. All of agriculture contributed almost 354,000 jobs (9.5% of Wisconsin's total employment), $21.2 billion in labor income (8.7% of the state total), and $37.8 billion in total income (9.4% of the state total). The employment estimates were about 81,800 jobs lower in 2022 than in 2017 (18.8% decline) and total labor income attributable to Wisconsin agriculture was $1.2 billion lower than in 2017 (5.5% decline), but total income increased by $143.0 million (0.4%) over 2017 levels.

As in prior years, the bulk of the economic contribution came from food processing. In 2022, food processing contributed $107.0 billion to total industrial revenues (sales), 298,400 jobs, $18.7 billion to labor income, and $32.4 billion to total income. This compares to $30.5 billion in industrial revenues for on-farm activities, 143,700 jobs, $6.4 billion in labor income, and $13.7 billion in total income. There were two primary reasons why the contribution of food processing dominates on-farm activities. First, in terms of simple industrial revenues, food processing accounted for $28.37 billion (before the multiplier effects are accounted for), and on-farm revenues accounted for $18.96 billion (again, before the multiplier effects are accounted for). Further, the income flowing to workers (labor income) was much higher in food processing than on-farm activities. Industry-wide averages, the typical job in food processing, had an income of $82,070 compared to $35,500 in on-farm activity. Because the stronger "purchasing power" of the typical food processing worker was higher than the typical on-farm worker, the resulting "induced effects" embedded in the multiplier (i.e., the impact of workers spending income in the regional economy) was larger for food processing.

The second reason is how the economic multiplier reflects the impacts of the input supply chain and as such could be described as "backwards looking". For farm operations, this would include inputs to the farm along with farm labor spending income in the local community. For food processors, a sizeable part of input supply chains includes the farm operators. Consider a vegetable processing facility (canning) compared to a vegetable farmer. Here the vegetable farmer's major expenditures are on labor (including returns to the farmer), support activities for agricultural production, real estate services (e.g., land rental), pesticides and other agricultural chemicals, and agricultural-related wholesale trade, among others. For canning processors (vegetables and fruits) the major expenses are on labor (including returns to the business), trucking services, metal cans, paperboard containers, and raw vegetables (and fruits), among others. The fact that the basic vegetable commodities are in the supply chain means that the multiplier captures a significant portion of the vegetable farming sector itself. Thus, the contribution analysis of food processing captures a large proportion of on-farm operations, and for this reason, the contribution of food processing dominates on-farm activities.

Now consider the contribution of dairy, the dominant agricultural sector in Wisconsin. In 2022 the dairy industry (on-farm and processing) contributed $52.8 billion to total industrial revenues, or 6.5% of the state total, 120,700 jobs (3.3% of the state total employment), $7.9 billion to labor income (3.2% of the state total), and $13.7 billion to total income (3.4% of state total). Compared to the contribution of dairy in 2017, this represented a 16.0% increase in total industrial revenues (sales), but a decline in employment (23.2%), labor income (12.5%), and total income (9.0%). Looking more closely at farm activity, dairy farms contributed $15.2 billion to industrial revenues, 48,800 jobs, $2.6 billion to labor income, and $5.2 billion to total income. As expected, dairy processing had a much larger contribution to the Wisconsin economy because of the relatively larger share of employment and the inclusion of dairy farms in the input supply chain of dairy processors. If we remove the feedback effects of dairy processing on dairy farms, the dairy processing sector contributed $37.1 billion to industrial revenues (about 70% of the total contribution of all dairy), 70,200 jobs (58.1% of all dairy contribution), $5.1 billion to labor income (65.2% of all dairy contribution) and $8.3 billion to total income (60.7% of all dairy contribution).

In addition to supporting industrial revenues, employment, and income, the economic activity associated with agriculture also generates tax revenues for all levels of government. For example, workers pay income, sales, and property taxes, and businesses pay a range of taxes as part of their operations. In addition, there are taxes generated through the multiplier effects. In 2022, all agricultural activity generated $7.8 billion in tax revenues, with 64.7% ($5.1 billion) flowing to the federal government, 22.6% ($1.8 billion) to state government, and 12.7% ($997.2 million) to local governments. Given federal income taxes, contributions to Social Security and Medicare/Medicaid taxes (i.e., FICA taxes), and the federal unemployment tax, federal tax revenue expectedly dominated state and local income and sales taxes. Dairy generated about $3.0 billion in total tax revenues, and a majority came from dairy processing-related activities. Dairy also contributed $704.2 million to state government revenues and $430.0 million to local government revenues.

Table 3a Contribution of Agriculture to the Wisconsin Economy: 2022

	Employment	Labor Income (MM$)	Total Income (MM$)	Industry Revenues (MM$)
All On Farm	143,690	$6,374.30	$13,691.63	$30,464.91
Food Processing	298,433	$18,708.93	$32,408.44	$106,978.01
All of Agriculture	353,932	$21,219.38	$37,782.56	$116,279.26
Dairy On Farm	48,786	$2,648.65	$5,203.21	$15,228.73
Dairy Processing	118,954	$7,792.03	$13,527.50	$52,291.36
All Dairy	120,708	$7,887.28	$13,714.64	$52,838.87
Forestry and Fishing	7,445	$332.44	$488.11	$793.65

Table 3b Contribution of Agriculture to the Wisconsin Economy: 2022

	Employment	Labor Income	Total Income	Industry Revenues
All On Farm (%)	3.9	2.6	3.4	3.7
Food Processing (%)	8.1	7.7	8.1	13.1
All of Agriculture (%)	9.5	8.7	9.4	14.3
Dairy On Farm (%)	1.3	1.1	1.3	1.9
Dairy Processing (%)	3.2	3.2	3.4	6.4
All Dairy (%)	3.3	3.2	3.4	6.5
Forestry and Fishing (%)	0.20	0.1	0.1	0.1

Table 4 Fiscal Impacts on Government

	Local Govt (MM$)	State Govt (MM$)	Federal Govt (MM$)	Total (MM$)
All On Farm	$332.24	$621.75	$1,557.56	$2,511.55
Food Processing	$918.78	$1,578.70	$4,479.95	$6,977.43
All Agriculture	$997.24	$1,778.51	$5,084.91	$7,860.66
Dairy On Farm	$212.48	$309.85	$640.27	$1,162.61
Dairy Processing	$422.40	$693.02	$1,868.70	$2,984.12
All Dairy	$430.05	$704.17	$1,891.72	$3,025.94
Forestry-Fishing	$16.25	$26.48	$72.26	$114.99

Sub-State Analysis

To gain further insights into this regional variation separate economic models (input-output) were generated for nine sub-regions of the state as defined by the National Agricultural Statistical Agency Agricultural activity, whether on-farm or food processing, is not evenly distributed across Wisconsin. Prior analysis of the contribution of agriculture consistently revealed that some parts of Wisconsin were more dependent upon farm activities, while others were more dependent on food processing. In two regions, the North Central[8] and the Southwest,[9] agriculture and food processing contributed more than one-fifth of total regional economic activity (Table 5a and 5b). For the Southwest, 27.4% of total industrial revenues depend on agricultural activity. In terms of total economic activity, the largest contribution of agriculture to industrial revenues was in the East Central[10] with a total contribution of $25.87 billion (15.7% of the regional total). The source of the contributions varied across these three regions with food processing dominating in the East Central and North Central regions, but on-farm activity made up a larger share in the Southwest region. This regional variation is evident in a simple mapping of the aggregate contribution to industrial revenues in Figures 9a-9c. The three other measures of economic activity – employment, labor income, and total income – followed similar patterns across Wisconsin.

When compared to the 2017-focused analysis, there are mixed messages. On the one hand, seven of the nine regions experienced a modest increase in the total contribution to industrial sales. The two exceptions, the Southeast and South Central, experienced modest declines. On the other hand, agriculture's share of total economic activity in eight of the nine regions declined. Only the North Central experienced an increase (21.8% in 2017 and 22.6% in 2022). In summary, the size of the non-agricultural sectors in these regional economies grew at a faster rate than agriculture.

Narrowing our focus on dairy, the East Central region was the largest contributor (Figure 10a) with a total impact of $13.3 billion accounting for 8.1% of total economic activity. As with all agricultural activity, the Southwest region of Wisconsin was the most heavily dependent upon dairy, which accounts for 18.1% of total economic activity. Similar to the statewide analysis, the bulk of the contribution of dairy to each regional economy was from dairy processing, which was dominated by cheese production. Compared to the 2017 dairy contribution analysis, five of the nine regions experienced an increase in the total contribution to industrial revenues, but four experienced a decline. Most of the changes were relatively modest. The Northwest[11] region, for example, declined from $1.79 billion in 2017 to $1.69 billion in 2022. But a handful experienced a meaningful increase. The East Central region went from $11.37 billion in 2017 to $13.31 billion in 2022, and the North Central region went from $4.66 billion in 2017 to $7.09 billion in 2022. Examining changes in the percent of total economic activity attributed to all dairy activity, we see a similar pattern with all of agriculture: For much of Wisconsin, the growth in dairy was more modest than non-agricultural growth in the economy, and, therefore, the percentage shares tended to decline.

8 The North Central region is composed of Ashland, Clark, Iron, Lincoln, Marathon, Oneida, Price, Taylor andVilas counties.
9 The South West region is composed of Crawford, Grant, Iowa, Lafayette, Richland, Sauk and Vernoncounties.
10 The East Central region is composed of Brown, Calumet, Door, Kewaunee, Fond Du Lac, Manitowoc, Outagamie, Sheboygan, and Winnebago counties.
11 The North West region is composed of Barron, Bayfield, Burnett, Chippewa, Douglas, Polk, Rusk, Sawyerand Washburn counties.

Table 5a Contribution of Agriculture to the Wisconsin Economy: Substate Regional Analysis

	South East	East Central	North East	North Central	Central	North West	West Central	South West	South Central
Industry Revenues (MM$)									
On-Farm	$1,257.63	$4,707.32	$1,285.90	$2,291.42	$2,195.57	$1,577.72	$3,452.60	$3,134.77	$3,997.43
Food Processing	$12,370.01	$22,758.92	$1,773.10	$8,911.53	$4,617.43	$3,949.54	$8,999.38	$5,441.90	$13,968.74
All Agriculture	$13,432.84	$25,874.81	$2,757.30	$9,904.42	$6,302.86	$5,001.74	$11,528.55	$7,401.17	$16,912.51
On-Farm Dairy	$397.66	$2,976.67	$730.20	$1,439.36	$738.22	$713.17	$1,340.39	$1,327.13	$1,672.38
Dairy Processing	$1,321.26	$11,555.31	$997.60	$6,776.60	$1,647.41	$1,391.73	$4,898.39	$4,609.53	$5,587.50
All Dairy	$1,607.88	$13,311.97	$1,493.90	$7,086.97	$2,027.19	$1,696.00	$5,676.56	$4,875.99	$6,264.75
Employment									
On-Farm	6,786	20,556	6,254	11,643	11,182	9,870	18,340	17,116	19,166
Food Processing	30,140	48,340	4,130	18,748	11,131	9,409	22,009	11,725	32,707
All Agriculture	36,190	63,597	9,386	25,357	20,106	17,086	36,214	24,374	47,318
On-Farm Dairy	1,168	9,062	2,282	4,544	2,207	2,682	4,329	4,346	5,052
Dairy Processing	2,259	19,433	1,825	12,057	3,068	2,971	8,869	8,510	10,028
All Dairy	3,084	24,833	3,385	13,068	4,084	4,124	11,393	9,414	11,966
Labor Income (MM$)									
On-Farm	$242.11	$953.23	$262.50	$494.94	$395.45	$302.52	$591.46	$611.53	$818.72
Food Processing	$2,178.34	$3,424.07	$225.80	$1,134.58	$627.42	$498.49	$1,384.52	$606.01	$2,098.75
All Agriculture	$2,401.28	$4,104.84	$450.90	$1,423.97	$951.22	$741.06	$1,857.23	$1,059.73	$2,761.45
On-Farm Dairy	$52.59	$489.26	$111.60	$238.69	$89.84	$99.65	$171.31	$185.58	$243.54
Dairy Processing	$159.19	$1,446.16	$106.60	$783.43	$165.58	$151.59	$606.49	$469.88	$643.69
All Dairy	$196.83	$1,741.49	$184.50	$831.53	$206.78	$196.67	$709.08	$506.74	$744.01
Total Income (MM$)									
On-Farm	$630.18	$1,921.06	$525.20	$960.46	$1,052.81	$686.16	$1,496.97	$1,419.18	$1,824.23
Food Processing	$3,637.13	$5,353.00	$383.10	$1,912.06	$1,136.41	$866.36	$2,411.56	$1,118.93	$3,632.38
All Agriculture	$4,193.00	$6,734.00	$810.30	$2,440.57	$2,012.28	$1,387.78	$3,589.30	$2,170.43	$5,162.00
On-Farm Dairy	$120.48	$904.39	$213.20	$451.92	$216.40	$211.29	$402.99	$396.47	$533.11
Dairy Processing	$286.35	$2,294.65	$179.80	$1,358.33	$310.85	$266.71	$1,083.54	$868.66	$1,072.23
All Dairy	$372.11	$2,834.27	$326.50	$1,452.10	$420.66	$357.53	$1,318.68	$949.89	$1,296.03

Table 5b Contribution of Agriculture to the Wisconsin Economy as a Share of Region Total: Substate Regional Analysis

	South East	East Central	North East	North Central	Central	North West	West Central	South West	South Central
Industry Revenues (%)									
On-Farm	0.5	2.9	8.6	5.2	6.5	4.6	5.2	11.6	2.6
Food Processing	4.4	13.8	11.9	20.4	13.7	11.6	13.6	20.2	9.2
All Agriculture	4.8	15.7	18.5	22.6	18.7	14.7	17.4	27.4	11.1
On-Farm Dairy	0.1	1.8	4.9	3.3	2.2	2.1	2	4.9	1.1
Dairy Processing	0.5	7	6.7	15.5	4.9	4.1	7.4	17.1	3.7
All Dairy	0.6	8.1	10	16.2	6	5	8.6	18.1	4.1
Employment (%)									
On-Farm	0.5	3	8.4	6	7	6.5	5.5	12.8	2.8
Food Processing	2.3	7.1	5.5	9.7	7	6.2	6.7	8.8	4.8
All Agriculture	2.8	9.4	12.6	13.1	12.7	11.2	11	18.3	6.9
On-Farm Dairy	0.1	1.3	3.1	2.4	1.4	1.8	1.3	3.3	0.7
Dairy Processing	0.2	2.9	2.4	6.2	1.9	2	2.7	6.4	1.5
All Dairy	0.2	3.7	4.5	6.8	2.6	2.7	3.4	7.1	1.8
Labor Income (%)									
On-Farm	0.3	2.1	6.8	4.4	4.4	3.8	3	8.4	1.7
Food Processing	2.4	7.7	5.9	10.2	7	6.2	7.1	8.3	4.3
All Agriculture	2.6	9.3	11.7	12.8	10.6	9.2	9.5	14.6	5.7
On-Farm Dairy	0.1	1.1	2.9	2.1	1	1.2	0.9	2.6	0.5
Dairy Processing	0.2	3.3	2.8	7	1.8	1.9	3.1	6.5	1.3
All Dairy	0.2	3.9	4.8	7.5	2.3	2.4	3.6	7	1.5
Total Income (%)									
On-Farm	0.4	2.6	8.1	5.2	6.8	4.8	4.7	11.5	2.3
Food Processing	2.5	7.3	5.9	10.3	7.3	6.1	7.5	9.1	4.5
All Agriculture	2.8	9.2	12.5	13.1	12.9	9.7	11.2	17.6	6.4
On-Farm Dairy	0.1	1.2	3.3	2.4	1.4	1.5	1.3	3.2	0.7
Dairy Processing	0.2	3.1	2.8	7.3	2	1.9	3.4	7	1.3
All Dairy	0.3	3.9	5.1	7.8	2.7	2.5	4.1	7.7	1.6

Figure 9 All Agriculture Contribution to Industrial Revenues (MM$)

Figure 9a All Agriculture Contribution to Industrial Revenues (MM$)

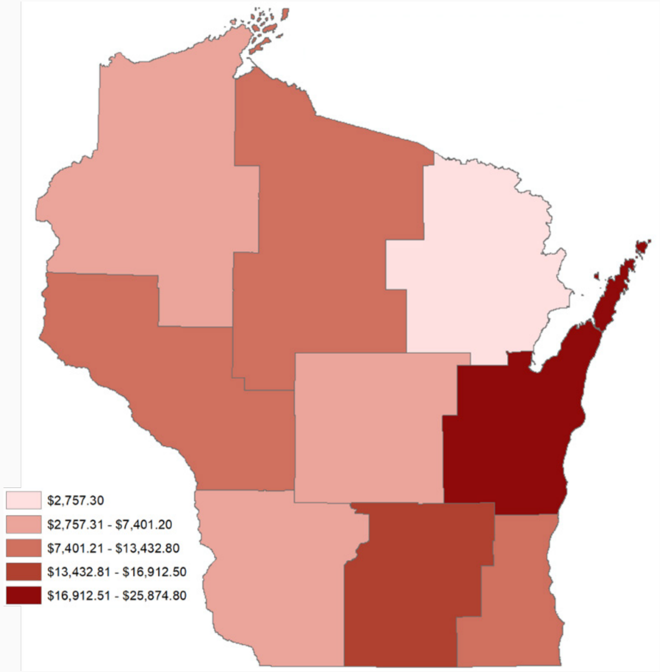


Figure 9b On Farm Contribution to Industrial Revenues (MM$)

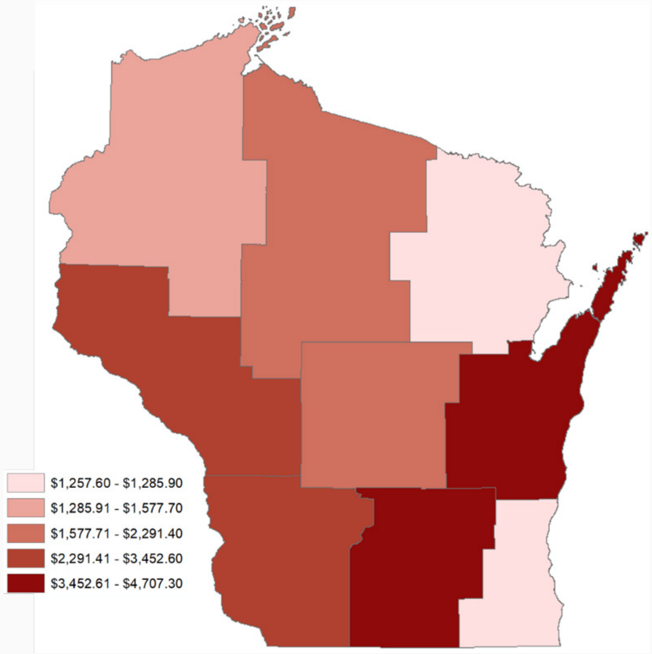


Figure 9c Food Processing Contribution to Industrial Revenues (MM$)

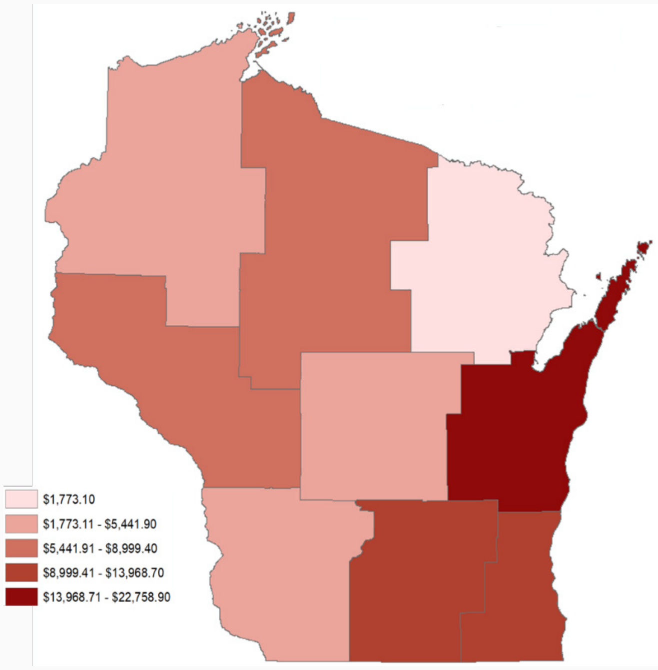


Figure 10 Dairy Processing Contribution to Industrial Revenues (MM$)

Figure 10a All Dairy Contribution to Industrial Revenues (MM$)

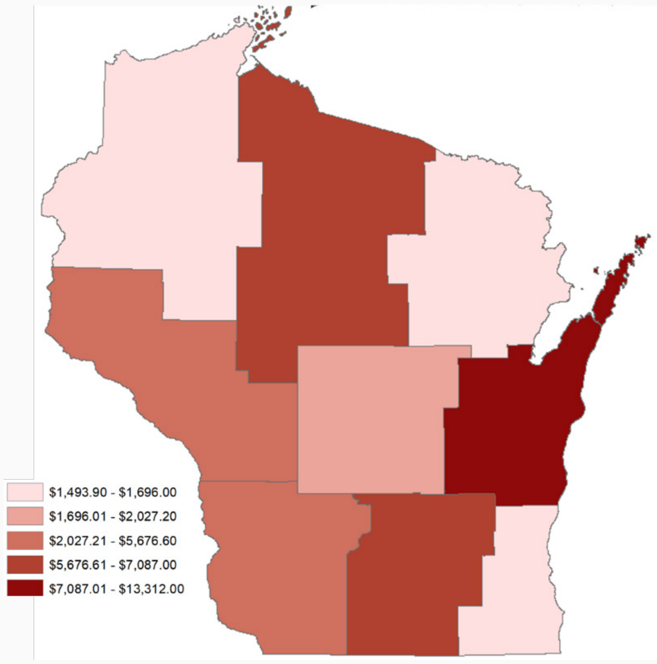


Figure 10b Dairy on Farm Contribution to Industrial Revenues (MM$)

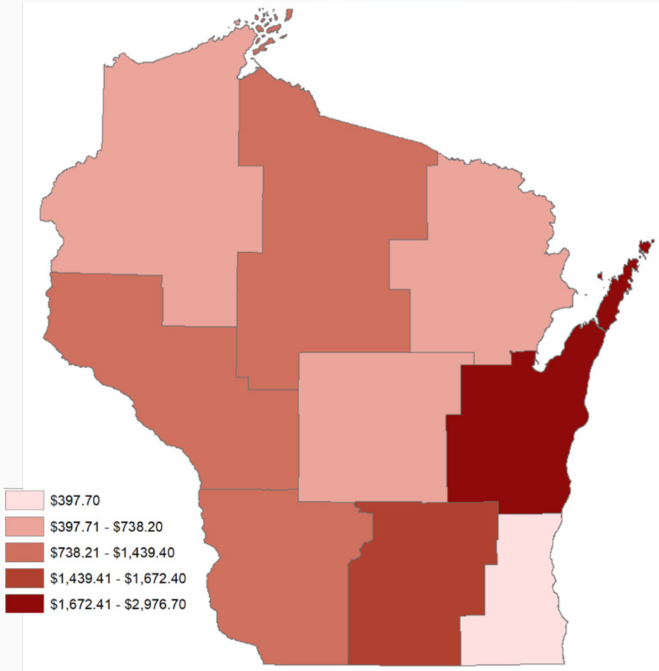
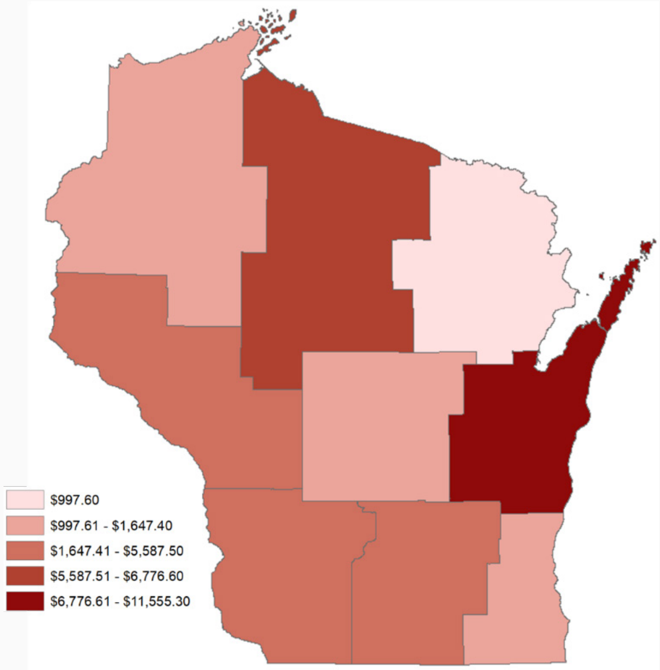


Figure 10c Dairy Processing Contribution to Industrial Revenues (MM$)



Environmental Impacts

As highlighted thus far, Wisconsin agriculture plays a pivotal role in the State's economy, contributing a significant share of the State's GDP and earnings. It is important to recognize that with the size of the industry, there are also consequences for the State's natural resources. Increasingly, agricultural and food businesses and public entities are expected to maintain a detailed accounting of environmental contributions at every stage of their supply chain, including the production of raw agricultural commodities. While some of the shifts in agri-environmental policy and regulations may carry costly implications for Wisconsin agriculture, farms and food processors that reduce their environmental footprints can leverage new policies and markets to add value in non-traditional ways to their operations. Thus, having a baseline understanding of the environmental contributions of the State's agricultural sector can be informative to the economic opportunities that lie ahead. The goal of this section is to provide a brief discussion about the environmental implications of agriculture in Wisconsin based on similar methods used by federal agencies to track industrial emissions.

We will focus on three key measures of environmental impact: Greenhouse Gas Emissions (in millions of metric tons of carbon dioxide equivalent), Nitrogen and Phosphorus Releases (in metric tons), and Water Withdrawals (in acre-feet of water). The methodology in this section mirrors the economic contributions using IMPLAN's input-output framework.

We report both on-farm and food-processing environmental impacts from the agricultural industry to be consistent with the contribution analysis. These results also account for direct, indirect, and induced (see appendix for definitions) activities so that the economic and environmental impacts are interpreted on equal footing. In that regard, it is worthwhile clarifying that our reported environmental contributions may exceed traditional values (i.e. direct only) reported by some agencies. The same logic applies to the economic contributions: The total industry revenue we report above exceeds typical annual cash receipts statistics because this analysis incorporates downstream impacts of the industry's expansion.

Table 6 reports the state-level summary of these measures. In what follows, we will discuss each environmental metric separately and their implications for the industry moving forward. We will discuss contributions from the direct and indirect channels for each of the measures and disaggregate the impacts regionally and between the dairy and non-dairy sectors. Where a good industry comparison exists, we will compare agriculture's environmental impact with several other sectors of Wisconsin industry to provide context for the measures. Note that because agricultural processing has feedback effects on farm activity, we can not simply add the separate farm and processing impacts together for the total environmental impacts as those feedback effects would result in double counting.

12 A caveat worth noting in this framework is that the coefficients of per unit (e.g. per dollar of revenue) impact are based on nationwide estimates. If Wisconsin is more/less environmentally efficient atproducing a given unit of product than other states, this analysis will understate/overstate the actual environmental impact. In the future, IMPLAN and the EPA hope to have state-specific coefficients of environmental efficiency for a more accurate environmental impact.

Table 6 Contribution of Wisconsin Agriculture to Environmental Resources: 2022

	GHG MMTCO2e	Nitrogen and Phosphorus Million Lbs	Water Use Millions AF
All On Farm	8.22	179.91	4.54
Food Processing	14.13	87.7	2.68
All Agriculture	17.78	179.91	4.78
Dairy On Farm	3.49	25.83	0.59
Dairy Processing	6.88	25.28	0.66
All Dairy	7	26.21	0.68
Forestry-Fishing	0.14	0.15	0.01

Greenhouse Gas Emissions

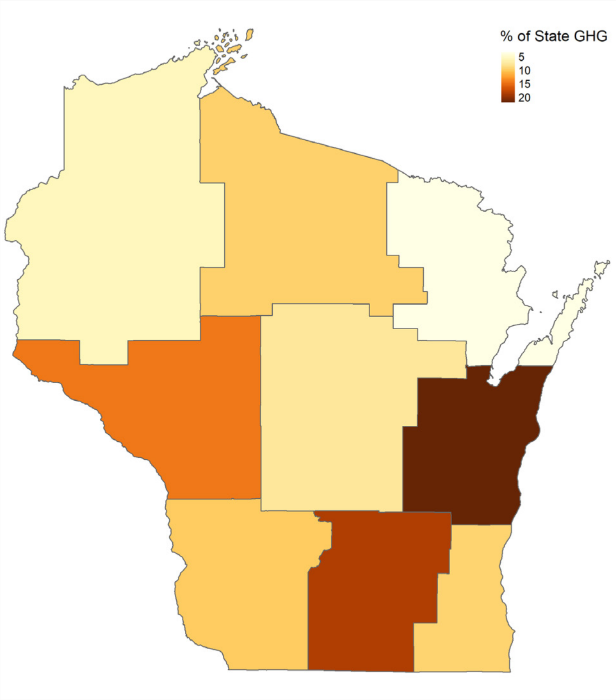
Reducing global greenhouse gas emissions (GHGs) is one of the most highly discussed and controversial environmental challenges of our time. Almost all countries have implemented climate or carbon policies in the last decade to limit the impacts of climate change. These policies include subsidies for renewable energy generation, cap and trade systems, and carbon taxation. While agriculture is only a part of the contributor to global greenhouse gas emissions (estimates range from 10-26%; e.g. see U.S. EPA, 2024 and Ritchie, 2019), agriculture plays a critical role in reaching local and global greenhouse gas reduction targets. In this section, we develop a baseline for Wisconsin agriculture's greenhouse gas contributions and which channels and regions are the largest contributors.

The EPA estimates that all industries in the state of Wisconsin annually emit about 122.5 million metric tons of carbon dioxide equivalent (MMTCO2e) (U.S. EPA, 2024). As shown in Table 6, we report that agriculture contributes 17.7 MMTCO2e or 14% of the state total. This number includes both the direct and indirect effects of agricultural production. The direct effect – which is driven by the cultivation of soils, enteric emissions from ruminant livestock, nitrous oxide from synthetic fertilizers and manure, and carbon dioxide from machinery -- accounts for about 95% of the GHG impact from agricultural activity. While the indirect effect -- which largely results from agriculture's demand for energy and transportation -- accounts for the other 5%. For comparison, the entire transportation sector in the state contributes 18.7 MMTCO2e or 15% of the State's total. It is also important to note that agriculture and forestry also have the potential to sequester carbon, which may partially offset these impacts, but agriculture as a whole is still a net positive emitter of greenhouse gases.

Of the agricultural total, grain farming, dairy, and beef are the leading contributors to GHG emissions in agriculture in that order, which is unsurprising given that these are also the three leading commodities in terms of sales. We give special attention to the dairy sector. Dairy and dairy processing contribute 7 MMTCO2e from direct and indirect activities. A subregional breakdown of the State's aggregate GHG emissions is provided in Figure 11, with the East Central region contributing the most at 21%, driven by the heavy share dairy and dairy processing in the region.

These physical contributions can be converted to monetary values for the sake of cost-benefit analyses of policy abatement options. The social cost of carbon measures the monetary value of damages from every ton of carbon emitted. Most of the U.S. government uses a social cost of carbon estimates that range from $51 to $190 per ton of CO2e. Given these values and the physical carbon emissions from agriculture, we can roughly calculate that Wisconsin agriculture contributes between $902 million and $3.3 billion worth of greenhouse gas-related damages annually. A key question for policy is whether changes to agricultural practices, technology, land use, and supply chains can reduce or sequester carbon in a cost-effective manner.

Figure 11 Greenhouse Gas Emissions from Agriculture by Region

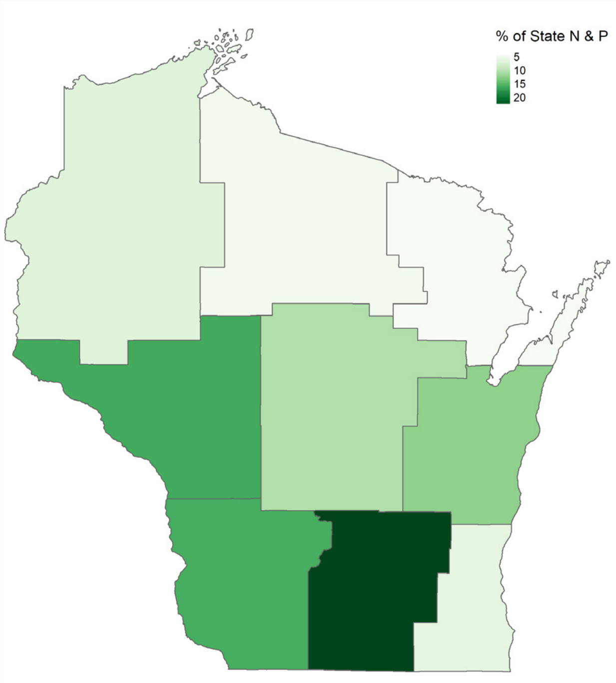


Nitrogen and Phosphorus

Wisconsin's water resources are an important amenity for the livability of the state and play an important role in many industries. As many Wisconsin residents are all too aware, water quality degradation threatens human health, property values, safe drinking water, aquatic life, and outdoor recreation. Much, but certainly not all, of water pollution in the state results from nitrogen and phosphorus fertilizers used for agriculture. This has led to a renewed focus from the state legislature to reduce nonpoint source pollution on-farm and optimize fertilizer application, like the Producer-Led Watershed Grant Program, the Nitrogen Optimization Pilot Program, the Crop Insurance Rebates for Planting Cover Crop, among others. These programs are founded on the belief that implementing best management practices on-farm can meaningfully and sustainably reduce nitrogen and phosphorus leaching and runoff.

In total, all of agriculture emits 179 million lbs of nitrogen and phosphorus annually. The vast majority of this (89%) results from grain and oilseed farming. It is important to note that this methodology only tracks nitrogen and phosphorus from agricultural sources, and does not account for releases from other sectors, like municipal and wastewater treatment. The subregional contributions of nitrogen and phosphorus from agriculture are detailed in Figure 12. The pattern here largely matches row-crop production patterns in the state, with the South-Central region contributing the most in aggregate.

Figure 12	Nitrogen and Phosphorus Releases from Agriculture by Region

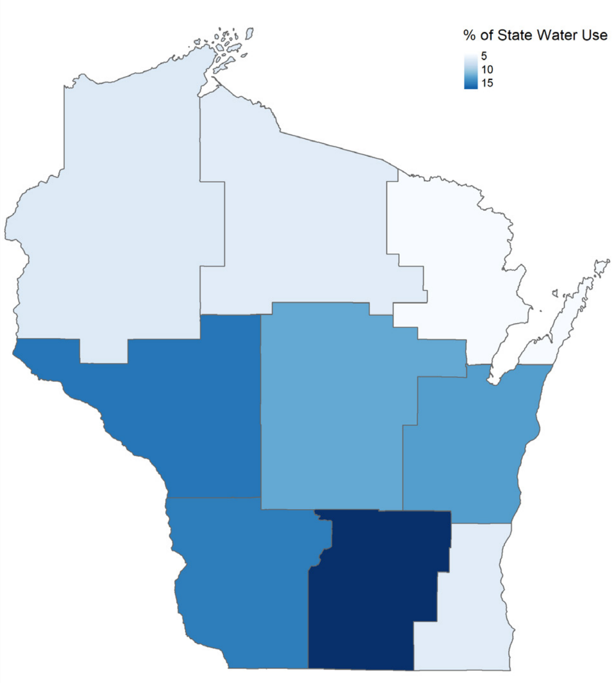


Water Withdrawals

Most of Wisconsin agriculture is dryland. According to the 2022 Ag Census, only about 475,000 acres of Wisconsin's total ag acreage is irrigated (about 3.5%). However, irrigation still serves a critical economic role in the Central Sands for high-value potatoes and processed vegetables. About 75% of those acres belong to operations with over $1 million in annual sales. Almost all of Wisconsin's irrigation water is sourced from groundwater aquifers (Hrozencik and Aillery, 2021). While precipitation is typically sufficient to recharge groundwater levels in the state, interannual fluctuations and drought can impose challenges to water access in some years, including interplays between ground and surface water. Wisconsin also has seen an uptick in irrigated acreage in the last two decades, meaning that agricultural water use may increasingly be important to monitor, especially in extreme years.

Like before, the subregion analysis for water use may not directly match traditional patterns of raw water use from the USDA census. In general, grain farming leads commodities in water withdrawals, and like Nitrogen and Phosphorus, the subregion breakdown largely matches grain farming. While the Central part of the state may use water more intensively (on a per acre basis), in aggregate, agriculture in the South Central part of the state contributes the most to water use.

Figure 13	Water Withdrawals from Agriculture by Region



Summary and Concluding Observations

Agriculture, both on-farm and food processing, remains an important part of Wisconsin's culture and economy. The state has a considerable comparative advantage in several agricultural sectors, including dairy, grain farming, and vegetable farming. These sectors are strengths of the state, in part, due to the complex network of infrastructure and supporting industries that work in tandem to support the industry as a whole and the economies of Wisconsin's rural communities. We also outline several key challenges that have defined the changing nature of the industry. In particular, on-farm economic activities are declining in general, and as a result, the contribution of on-farm agriculture to the State's economy is subsiding. With this trend, income from on-farm activity has grown smaller and more people have transitioned out of the industry. But at the same time, food processing in its many unique forms has grown in economic importance and created new opportunities for adding value to food production. Looking forward, a central challenge is identifying these opportunities to capitalize on this shift and discovering ways for both on-farm activities and food processing to best complement each other.

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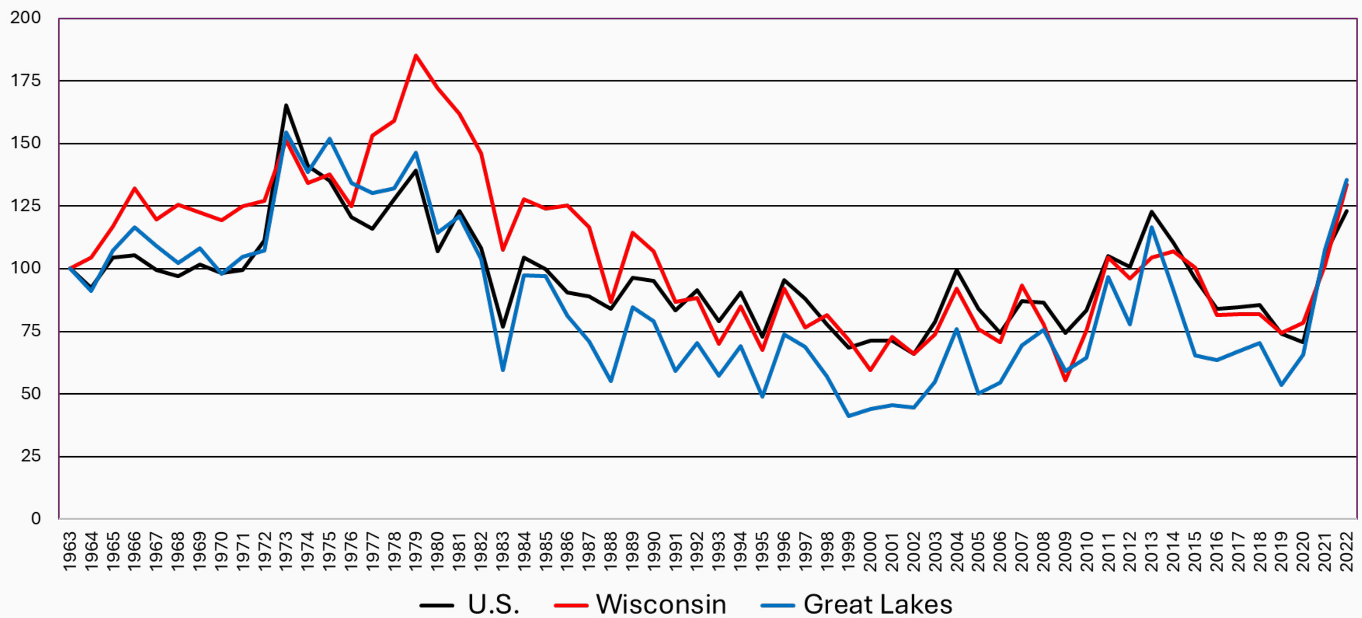
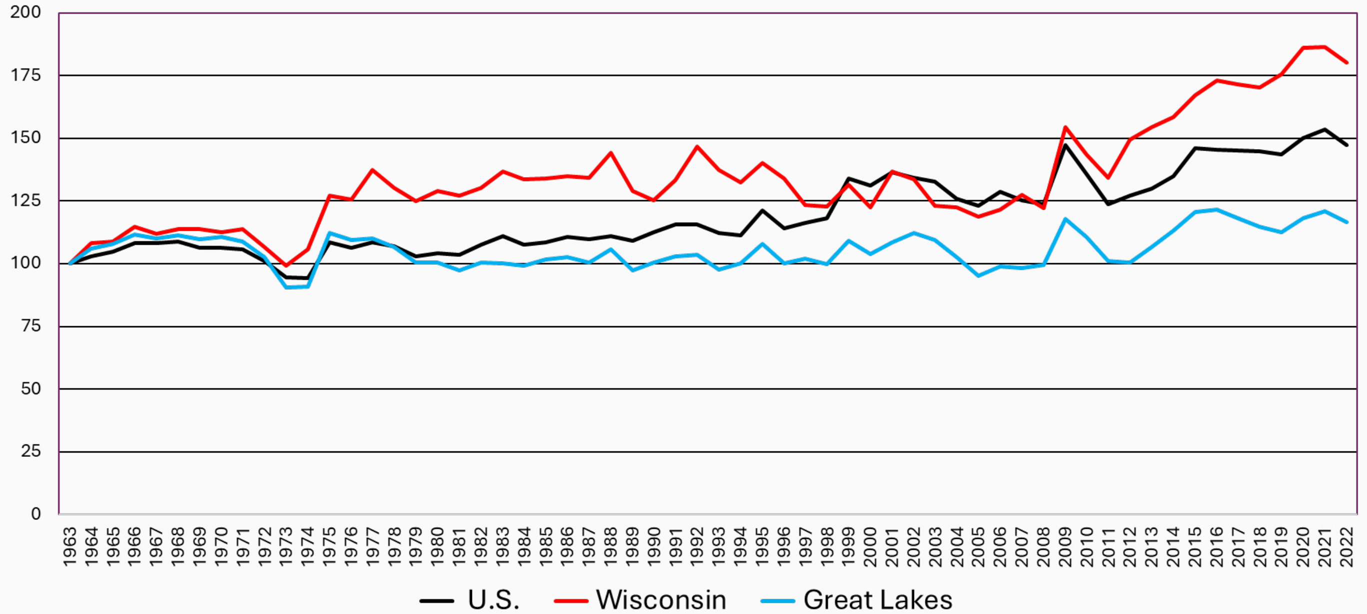
Appendix 1: Wisconsin, U.S., and Great Lakes States Historical Trends

Figure 1A On-Farm Gross Domestic Product Growth Index (in 2022 dollars)



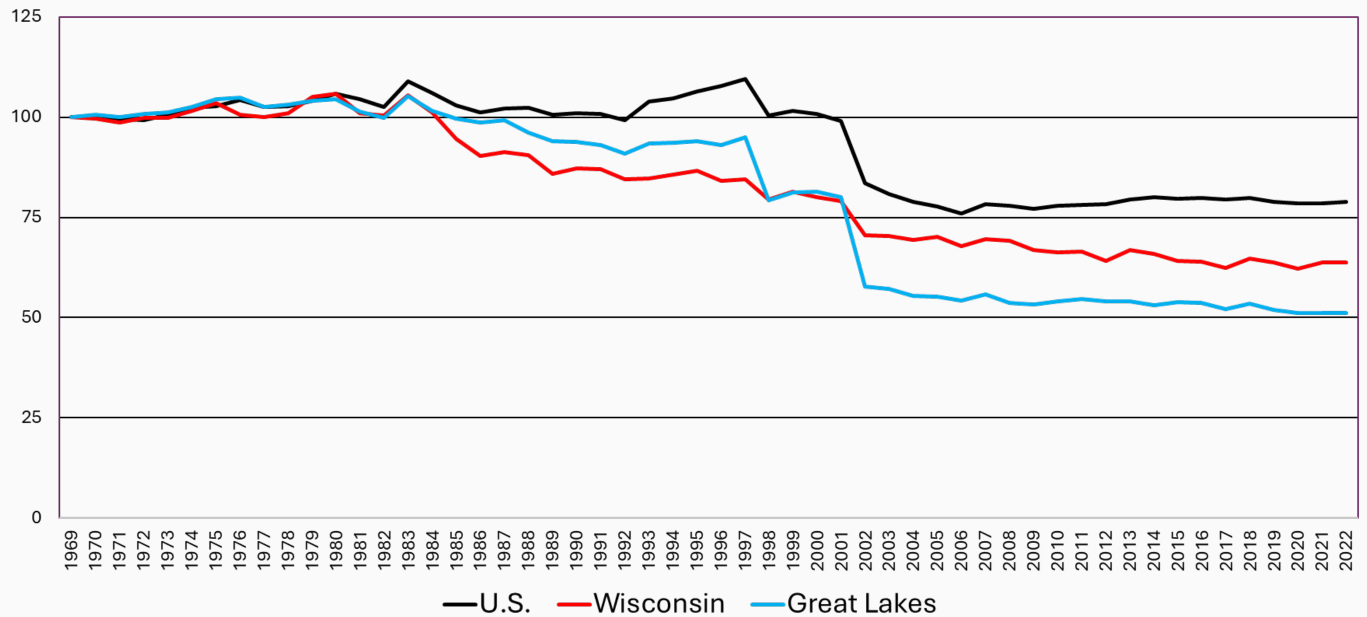
Source: BEA-REIS, calculations by the authors.

Figure 1B Food Processing Gross Domestic Product Growth Index (in 2022 dollars)



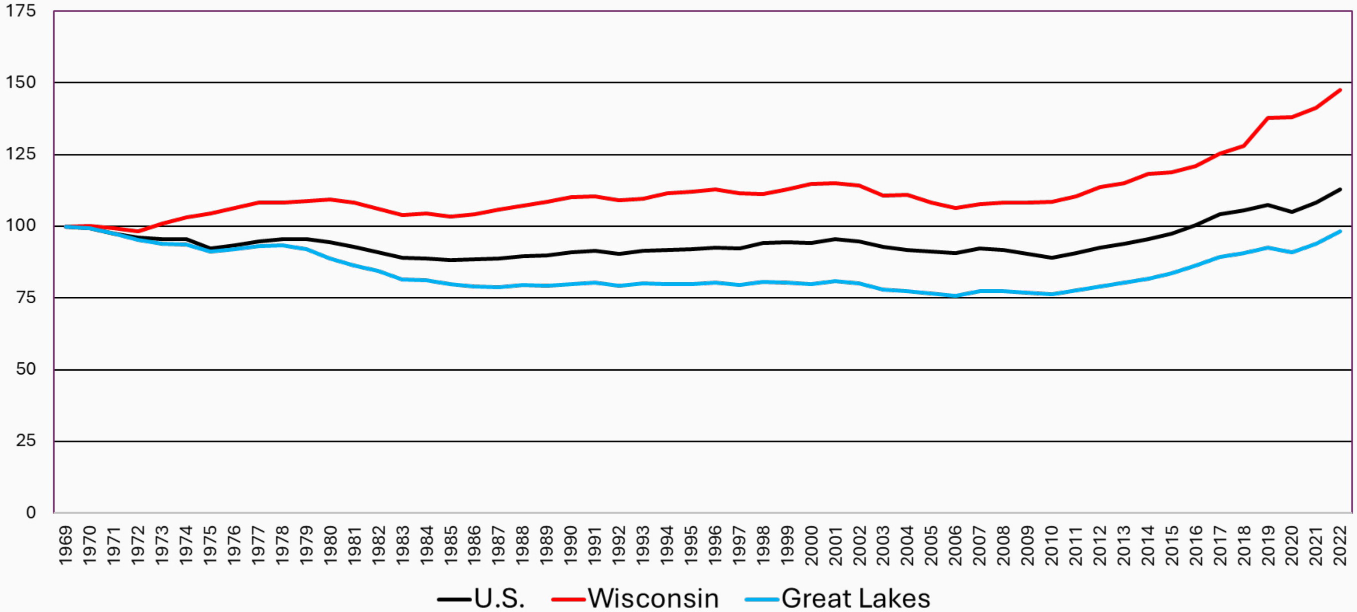
Source: BEA-REIS, calculations by the authors.

Figure 1C On-Farm Employment Growth Index



Source: BEA-REIS, calculations by the authors.

Figure 1D Food Processing Employment Growth Index



Source: BEA-REIS, calculations by the authors.

Appendix 2: Input-Output Modeling and Multipliers

Basics of Input-Output Modeling: We present a simple non-technical discussion of the formulation of input-output (IO) modeling in this section. An example of similar descriptive treatments would be Shaffer, Deller and Marcouiller (2004). An example of a more advanced discussion of input-output would be Miernyk (1965), and Miller and Blair (1985). As a descriptive tool, IO analysis represents a method for expressing the economy as a series of accounting transactions within and between the producing and consuming sectors. As an analytical tool, IO analysis expresses the economy as an interaction between the supply and demand for commodities. Given these interpretations, the IO model may be used to assess the impacts of alternative scenarios on the region's economy.

Transactions Table: A central concept of IO modeling is the interrelationship between the producing sectors of the region (e.g., manufacturing firms), the consuming sectors (e.g., households) and the rest of the world (i.e., regional imports and exports). The simplest way to express this interaction is through a regional transactions table (Table A1). The transactions table shows the flow of all goods and services produced (or purchased) by sectors in the region. The key to understanding this table is realizing that one firm's purchases are another firm's sales and that producing more of one output requires the production or purchase of more of the inputs needed to produce that product.

Table A1 Illustrative Transaction Table

	Purchasing Sectors (Buyers/Demand)			Final Demand		
Processing Sectors (Sellers/Supply)	Agr	Mfg	Serv	HH (labor)	Exports	Output
Agr	10	6	2	20	12	50
Mfg	4	4	3	24	14	49
Serv	6	2	1	34	10	53
HH (labor)	16	25	38	1	52	132
Imports	14	12	9	53	0	88
Inputs	50	49	53	132	88	372

The transactions table may be read from two perspectives: reading down a column gives the purchases by the sector named at the top of the column from each of the sectors named at the left. Reading across a row gives the sales of the sector named at the left of the row to those named at the top. In the illustrative transaction table for a fictitious regional economy (Table 1), reading down the first column shows that the agricultural firms buy $10 worth of their inputs from other agricultural firms. The sector also buys $4 worth of inputs from manufacturing firms and $6 worth from the service industry. Note that agricultural firms also made purchases from non-processing sectors of the economy, such as the household sector ($16) and imports from other regions ($14). Purchases from the household sector represent value added, or income to people in the form of wages and investment returns. In this example, agricultural firms purchased a total of $50 worth of inputs.

Reading across the first row shows that agriculture sold $10 worth of its output to agriculture, $6 worth to manufacturing, $2 worth to the service sector. The remaining $32 worth of agricultural output was sold to households or exported out of the region. In this case $20 worth of agricultural output was sold to households within the region and the remaining $12 was sold to firms or households outside the region. In the terminology of IO modeling, $18 (=$10+$6+$2) worth of agricultural output was sold for intermediate consumption, and the remaining $32 (=$20+$12) worth was sold to final demand. Note that the transactions table is balanced: total agricultural output (the sum of the row) is exactly equal to agricultural purchases (the sum of the column). In an economic sense, total outlays (column sum, $50) equal total income (row sum, $50), or supply exactly equals supply. This is true for each sector.

The transactions table is important because it provides a comprehensive picture of the region's economy. Not only does it show the total output of each sector, but it also shows the interdependencies between sectors. It also indicates the sectors from which the region's residents earn income as well as the degree of openness of the region through imports and exports. In this example, households' total income, or value added for the region is $132 (note total household income equals total household expenditure), and total regional imports is $88 (note regional imports equals regional exports). More open economies will have a larger percentage of total expenditures devoted to imports. As discussed below, the "openness" of the economy has a direct and important impact on the size of economic multipliers. Specifically, more open economies have a greater share of purchases, both intermediate and final consumption purchases, taking the form of imports. As new dollars are introduced (injected from exports) into the economy they leave the economy more rapidly through leakages (imports).

Direct Requirements Table: Important production relationships in the regional economy can be further examined if the patterns of expenditures made by a sector are stated in terms of proportions. This means that the proportions of all inputs needed to produce one dollar of output in a given sector can be used to identify linear production relationships. This is accomplished by dividing the dollar value of inputs purchased from each sector by total expenditures. Or, each transaction in a column is divided by the column sum. The resulting table is called the direct requirements table (Table A2).

The direct requirements table, as opposed to the transactions table, can only be read down each column. Each cell represents the dollar amount of inputs required from the industry named at the left to produce one dollar's worth of output from the sector named at the top. Each column essentially represents a `production recipe' for a dollar's worth of output. Given this latter interpretation, the upper part of the table (above households) is often referred to as the matrix of technical coefficients. In this example, for every dollar of sales by the agricultural sector, 20 cents worth of additional output from itself, 8 cents of output from manufacturing, 12 cents of output from services, and 32 cents from households will be required. In the example region, an additional dollar of output by the agricultural sector requires firms in agriculture to purchase a total of 40 cents from other firms located in the region. If a product or service required in the production process is not available from within the region, the product must be imported. In the agricultural sector, 28 cents worth of inputs are imported for each dollar of output. It is important to note that in IO analysis, this production formula, or technology (the column of direct requirement coefficients), is assumed to be constant and the same for all establishments within a sector. This assumption holds regardless of input prices or production levels.

Table A2 Illustrative Direct Requirements Table

	Purchasing Sectors (Buyers/Demand)		
Processing Sectors (Sellers/Supply)	**Agr**	**Mfg**	**Serv**
Agr	0.20	0.12	0.04
Mfg	0.08	0.08	0.06
Serv	0.12	0.04	0.02
HH (labor)	0.32	0.51	0.72
Imports	0.28	0.24	0.02
Inputs	1.00	1.00	1.00

Assuming the direct requirements table also represents spending patterns necessary for additional production, the effects of a change in final demand of the output on the other of sectors can be predicted. For example, assume that export demand for the region's agricultural products increases by $100,000. From Table 2, it can be seen that any new final demand for agriculture will require purchases from the other sectors in the economy. The amounts shown in the first column are multiplied by the change in final demand to give the following figures: $20,000 from agriculture, $8,000 from manufacturing, and $12,000 from services. These are called the direct effects and, in this example, they amount to a total impact on the economy of $140,000 (the initial change [$100,000] plus the total direct effects [$40,000]). For many studies of economic impact the direct and initial effects are treated as the same although there are subtle differences.

The strength of input-output modeling is that it does not stop at this point, but also measures the indirect effects of an increase in agricultural exports. In this example, the agricultural sector increased purchases of manufactured goods by $8,000. To supply agriculture's new need for manufacturing products, the manufacturing sector must increase production. To accomplish this, manufacturing firms must purchase additional inputs from the other regional sectors.

Continuing our $100,000 increase in export demand for a region's agricultural products, for every dollar increase in output, manufacturing must purchase an additional 12 cents of agricultural goods ($8,000 x .12 = $960), 8 cents from itself ($8,000 x .08 = $640), and 4 cents from the service sector ($8,000 x .04 = $320). Thus, the impact on the economy from an increase in agricultural exports will be more than the $140,000 identified previously. The total impact will be $140,000 plus the indirect effect on manufacturing totaling $1,920 ($960 + $640 + $320), or $141,920. A similar process examining the service sector increases the total impact yet again by $1,440 ([$12,000 x .04] + [$12,000 x .06] + [$12,000 x .02] = $1,440).

The cycle does not stop, however, after only two rounds of impacts. To supply the manufacturing sectors with the newly required inputs, agriculture must increase output again, leading to an increase in manufacturing and service sector outputs. This process continues until the additional increases drop to an insignificant amount. The total impact on the regional economy, then, is the sum of a series of direct and indirect impacts. Fortunately, the sum of these direct and indirect effects can be more efficiently calculated by mathematical methods. The methodology was developed by the Noble winning economist Wassily Leontief and is easily accomplished using computerized models.

Total Requirements Table: Typically, the result of the direct and indirect effects is presented as a total requirements table, or the Leontief inverse table (Table A3). Each cell in Table 3 indicates the dollar value of output from the sector named at the left that will be required in total (i.e., direct plus indirect) for a one dollar increase in final demand for the output from the sector named at the top of the column. For example, the element in the first row of the first column indicates the total dollar increase in output of agricultural production that results from a $1 increase in final demand for agricultural products is $1.28. Here the agricultural multiplier is 1.28: for every dollar of direct agricultural sales there will be an additional 28 cents of economic activity as measured by industry sales.

Table A3 Illustrative Total Requirements Table

	Purchasing Sectors (Buyers/Demand)		
Processing Sectors (Sellers/Supply)	**Agr**	**Mfg**	**Serv**
Agr	1.28	0.17	0.06
Mfg	0.12	1.11	0.07
Serv	0.16	0.07	1.03
Inputs	1.56	1.35	1.16

An additional interpretation of the transactions table, as well as the direct requirements and total requirements tables, is the measure of economic linkages within the economy. For example, the element in the second row of the first column indicates the total increase in manufacturing output due to a dollar increase in the demand for agricultural products is 12 cents. This allows the analyst to not only estimate the total economic impact but also provide insights into which sectors will be impacted and to what level.

Highly linked regional economies tend to be more self-sufficient in production and rely less on outside sources for inputs. More open economies, however, are often faced with the requirement of importing production inputs into the region. The degree of openness can be obtained from the direct requirements table (Table 2) by reading across the imports row. The higher these proportions are, the more open the economy. As imports increase, the values of the direct requirement coefficients must, by definition, decline. It follows then that the values making up the total requirements table, or the multipliers, will be smaller. In other words, more open economies have smaller multipliers due to larger imports. The degree of linkage can be obtained by analyzing the values of the off- diagonal elements (those elements in the table with a value of less than one) in the total requirements table. Generally, larger values indicate a tightly linked economy, whereas smaller values indicate a looser or more open economy.

Basics of Input-Output Multipliers: Through the discussion of the total requirements table, the notion of external changes in final demand rippling throughout the economy was introduced. The total requirements table can be used to compute the total impact a change in final demand for one sector will have on the entire economy. Specifically, the sum of each column shows the total increase in regional output resulting from a $1 increase in final demand for the column heading sector. Retaining the agricultural example, an increase of $1 in the demand for agricultural output will yield a total increase in regional output equal to $1.56 (Table 3). This figure represents the initial dollar increase plus 56 cents in direct and indirect effects. The column totals are often referred to as output multipliers.

The use of these multipliers for policy analysis can prove insightful. These multipliers can be used in preliminary policy analysis to estimate the economic impact of alternative policies or changes in the local economy. In addition, multipliers can be used to identify the degree of structural interdependence between each sector and the rest of the economy. For example, in the illustrative region, a change in the agriculture sector would influence the local economy to the greatest extent, while changes in the service sector would produce the smallest change. The output multiplier described here is perhaps the simplest input-output multiplier available. The construction of the transactions table and its associated direct and total requirements tables creates a set of multipliers ranging from output to employment multipliers. Input-output analysis specifies this economic change, most commonly, as a change in final demand for some product. Economists sometimes might refer to this as the "exogenous shock" applied to the system. Simply stated, this is the way we attempt to introduce an economic change.

The complete set includes:

Type	Definition
1. Output Multiplier	The output multiplier for industry i measures the sum of direct and indirect requirements from all sectors needed to deliver one additional dollar unit of output of i to final demand.
2. Income Multiplier	The income multiplier measures the total change in income throughout the economy from a dollar unit change in final demand for any given sector.
3. Employment Multiplier	The employment multiplier measures the total change in employment due to a one-unit change in the employed labor force of a particular sector.

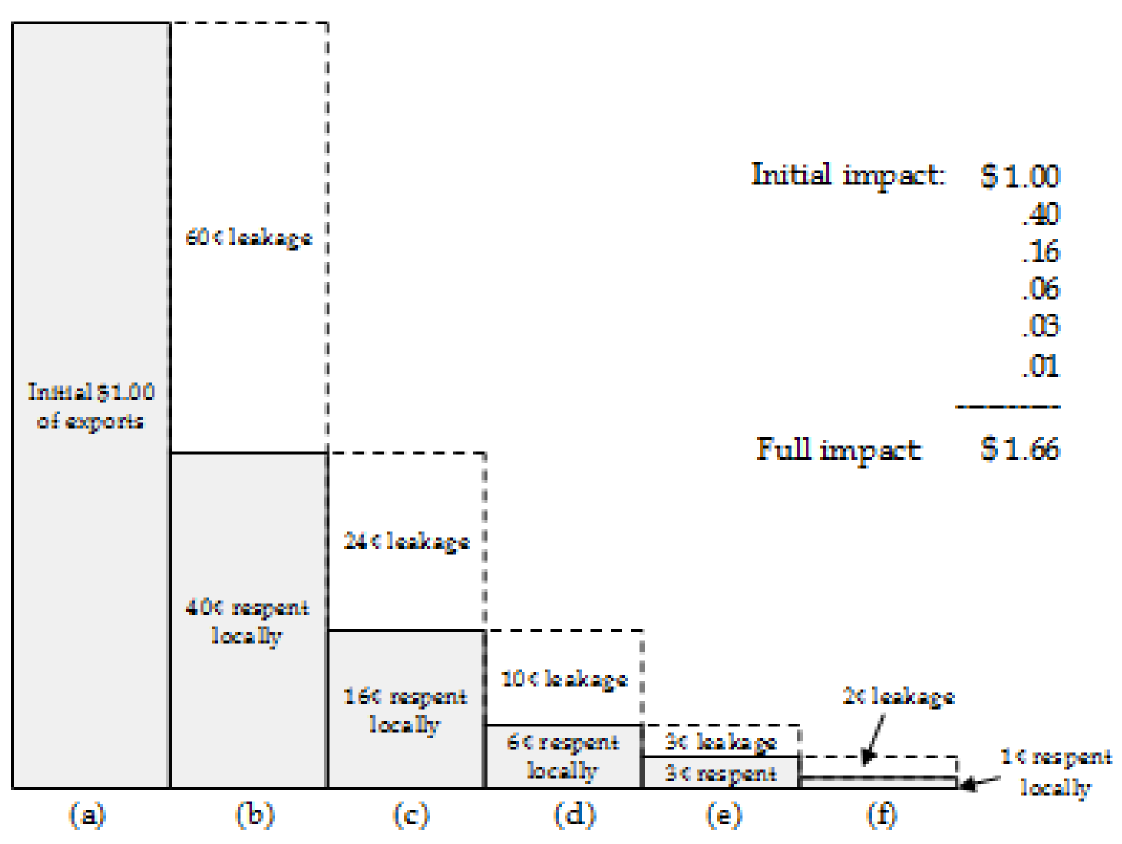
The income multiplier represents a change in total income (employee compensation plus proprietary income plus other property income plus indirect business taxes) for every dollar change in income for any given sector. The employment multiplier represents the total change in employment resulting from the change in employment in any given sector. Thus, we have three ways that we can describe the change in final demand.

Consider, for example, a dairy farm that has $1 million in sales (industry output), pays labor $100,000 inclusive of wages, salaries and retained profits, and that employs three workers, including the farm proprietor. Suppose that demand for milk produced at these farm increases 10 percent, or $100,000 dollars. We could use the traditional output multiplier to determine what the total impact on output would be. Alternatively, to produce this additional output the farmer may find that they need to hire a part-time worker. We could use the employment multiplier to examine the impact of this new hire on total employment in the economy. In addition, the income paid to labor will increase by some amount and we can use the income multiplier to see what the total impact of this additional income will have on the larger economy.

How are these income and employment multipliers derived if the IO model only looks at the flow of industry expenditures (output)? In the strictest sense, the IO does not understand changes in employment or income, only changes in final demand (sales or output). To do this we use the fact that the IO model is a "fixed proportion" representation of the underlying production technologies. This is most clear by reexamining the direct requirements table (Table 2). For every dollar of output (sales) inputs are purchased in a fixed proportion according to the production technology described by the direct requirements table. For every dollar of output there is a fixed proportion of employment required as well as income paid. In our simple dairy farm example, for every dollar of output there are .000003 (= 1,000,000 ÷ 3) jobs and $.10 (= 1,000,000 ÷ 100,000) in income. We can use these fixed proportions to convert changes in output (sales) into changes in employment and income.

Graphically, we can illustrate the round-by-round relationships modeled using input-output analysis. This is found in Figure 1. The direct effect of change is shown in the far left-hand side of the figure (the first bar (a)). For simplification, the direct effect of a $1.00 change in the level of exports, the indirect effects will spill over into other sectors and create an additional 66 cents of activity. In this example, the simple output multiplier is 1.66. A variety of multipliers can be calculated using input-output analysis.

While multipliers may be used to assess the impact of changes on the economy, it is important to note that such a practice leads to limited impact information. A more complete analysis is not based on a single multiplier, but rather, on the complete total requirements table. A general discussion of the proper and inappropriate uses of multipliers is presented in the next appendix to this text.



Initial, Indirect and Induced Effects: The input-output model and resulting multipliers described up to this point presents only part of the story. In this construction of the total requirements table (Table 3) and the resulting multipliers, the production technology does not include labor. In the terminology of IO modeling, this is an "open" model. In this case, the multiplier captures only the initial effect (initial change in final demand or the initial shock) and the impact of industry to industry sales. This latter effect is called the indirect effect and results in a Type I multiplier. A more complete picture would include labor in the total requirements table. In the terminology of IO modeling, the model should be "closed" with respect to labor. If this is done, we have a different type of multiplier, specifically a Type II multiplier, which is composed of the initial and indirect effects as well as what is called the induced effects.

The Type II multiplier is a more comprehensive measure of economic impact because it captures industry to industry transactions (indirect) as well as the impact of labor spending income in the economy (induced effect). In the terminology of IO analysis, an "open" model where the induced effect is not captured, any labor or proprietor income that may be gained (positive shock) or lost (negative shock) is assumed to be lost to the economy. In our simple dairy farm example, any additional income (wages, salaries and profits) derived from the change in output (sales) is pocketed by labor and is not re-spent in the economy. This clearly is not the case: any additional income resulting from more labor being hired (or fired) will be spent in the economy thus generating an additional round of impacts. This second round of impacts is referred to as the induced impact.

Insights can be gained by comparing and contrasting the indirect and induced effects. For example, industries that are more labor intensive will tend to have larger induced impacts relative to indirect. In addition, industries that tend to pay higher wages and salaries will also tend to have larger induced effects. By decomposing the Type II multiplier into its induced and indirect effects, one can gain a better understanding of the industry under examination and its relationship to the larger economy.

Misuses and Evaluation of Economic Multipliers: Multipliers are often misused or misunderstood. Problems frequently encountered in applying multipliers to community change include: (1) using different multipliers interchangeably; (2) double counting; (3) pyramiding; and (4) confusing multipliers with other economic measurements such as turnover and value added. Please note that if IMPLAN is used to generate the multipliers used in the analysis, many of the concerns outlined in this appendix are resolved.

(1) Interchanging Multipliers. As mentioned earlier, multipliers can be estimated for changes in business output, household income, and employment. These different multipliers are sometimes mistakenly used interchangeably. This should not be done because the sizes of the multipliers are different and because they measure completely different types of activity.

(2) Double Counting. Unless otherwise specified, the direct effect or initial change is included in all multiplier calculations. Consider, for example, a mining business multiplier of 2.20. The 2.20 represents 1.00 for the direct effect, and 1.20 for the indirect effects. The direct effect is thus accounted for by the multiplier and should not be added into the computation (double counted). A $440,000 total impact resulting from an increase of $200,000 in outside income (using the above 2.20 multiplier) includes $200,000 direct spending, plus $240,000 for the indirect effects. The multiplier effect is sometimes thought to refer only to the indirect effect. In this case, the initial impact is added to the multiplier effect, and is thereby counted twice—yielding an inflated estimate of change.

(3) Pyramiding. A more complicated error in using multipliers is pyramiding. This occurs when a multiplier for a non-basic sector is used in addition to the appropriate basic sector multiplier.

For example, sugar beet processing has been a major contributor to exports in many western rural counties. Assume the local sugar beet processing plant was closed and local officials wanted to determine the economic effect of the closing as well as the subsequent effect upon local farmers. The multiplier for the sugar beet processing sector includes the effect upon-farms raising sugar beets because the sugar beet crop is sold to local processors and not exported. Therefore, the processing multiplier should be used to measure the impact of changes in the sugar industry on the total economy. The impact estimate would be pyramided if the multiplier for farms, whose effects had already been counted, were added to processing.

Double counting and pyramiding are particularly serious errors because they result in greatly inflated impact estimates. If inflated estimates are used in making decisions about such things as school rooms or other new facilities, the results can be very expensive, indeed.

(4) Turnover and Value Added. Economic measurements incorrectly used for multipliers also result in misleading analysis. Two such examples are turnover and value added. Turnover refers to the number of times money changes hands within the community. In Figure 1, the initial dollar "turns over" five times; however, only part of the initial dollar is re-spent each time it changes hands. Someone confusing turnover with a multiplier might say the multiplier is 5, when the multiplier is actually only 1.66.

Value added reflects the portion of a product's total value or price that was provided within the local community. The value added would consider the value of a local raw product—like wheat delivered to the mill—and subtract that from the total wholesale value of the flour, then figure the ratio between the two. With cleaning losses, labor, bagging, milling, etc., the wholesale value may represent several times the value of the raw product and may be a fairly large number.

EVALUATING MULTIPLIERS

The determination of whether a multiplier is accurate can be a complicated procedure requiring time, extensive research, and the assistance of a trained economist. On the other hand, there are several questions that anyone who uses multipliers should ask. The test of accuracy for a multiple is captured in this question: How closely does that multiplier estimate economic relationships in the community (or region) being considered?

(1) Is the multiplier based on local data, or is it an overlay? Often, multipliers are used that were not developed specifically from data for that area. These multipliers are overlaid onto the area on the assumption that they will adequately reflect relationships in the economy. An example would be using the mining multiplier from a county in northwestern Wyoming to estimate a mining impact in northeastern Nevada.

A multiplier is affected by the economy's geographic location in relation to major trade centers. Areas where the trade center is outside the local economy have smaller multipliers than similar areas containing trade centers. Geographic obstacles en route to trade centers also affect a local economy. Multipliers for small plains towns are smaller than those for apparently comparable mountain towns, since plains residents usually do not face the same travel obstacles as mountain residents.

More services will characteristically develop in the mountain area because of the difficulty in importing services; the larger services base will lead to a larger multiplier effect.

The size of the economy will also influence multiplier size. A larger area generally has more businesses. This means that a given dollar is able to circulate more times before leaking than would be the case in a smaller area. Two economies with similar population and geographic size may have quite different multipliers depending on their respective economic structures. For example, if two areas have similar manufacturing plants, but one imports raw materials and the other buys materials locally, then the manufacturing multiplier for the two areas would be quite different.

The overlaying practice, when used appropriately, can save money and time and produce very acceptable results. It is often difficult to find a similar area where impact studies have been completed so that multipliers can be borrowed readily. An area's dollar flow patterns may be so unique, for example, that overlaying will not work.

(2) Is the multiplier based on primary or secondary data? Usually, there is more confidence in a multiplier estimated from data gathered in the community than in published or already-collected data. Primary data collection, though, is expensive and time consuming. Recent research has indicated that in some cases, there is little difference between multipliers estimated by primary or secondary data. In fact, primary data multipliers are not necessarily better than secondary data multipliers. While the type of secondary data needed for estimating multipliers may be available from existing sources, the format and/or units of measurement may not permit some multipliers to be estimated. The resulting adjustments made to use the existing data may cause errors. If secondary data is used, it may be advisable to consult individuals familiar with the data regarding its use.

(3) Aggregate versus disaggregate multipliers. As mentioned earlier in this publication, disaggregate multipliers are much more specific and therefore generally more trustworthy than aggregate multipliers. The accuracy required, and the time and money available most likely will determine whether the model will be aggregate or disaggregate. In many cases, an aggregated rough estimate may be sufficient.

(4) If you are dealing with an employment multiplier, is it based on number of jobs or full-time equivalent (FTE)? Employment multipliers are often considered to be the most important multipliers used in impact analysis. This is because changes in employment can be transmitted to changes in population, which in turn affect social service needs and tax base requirements. Employment multipliers can be calculated on the basis of number of jobs or on FTE. One FTE equals one person working full-time for one year. When multipliers are calculated on a number-of-jobs basis, comparisons between industries are difficult because of different definitions of part-time workers. For example, part-time work in one industry might be four hours per day, while in another it might be ten hours per week. If calculations were based on number of jobs, a comparison of multipliers would be misleading. The conversion of jobs to FTE also helps adjust for seasonal employment in industries such as agriculture, recreation, and forestry.

(5) What is the base year on which the economic model was formulated? Inflation can affect multipliers in two ways: (1) through changes in the prices of industry inputs, and (2) through changes in the purchasing patterns produced by inflation. Each input-output multiplier assumes that price relationships between sectors remain constant over time (at least for the period under consideration). In other words, the studies estimating multipliers assume that costs change proportionally: utility prices change at nearly the same rate as the cost of food, steel, and other commodities. If some prices change drastically in relation to others, then purchasing patterns and multipliers will likely change.

Marketing patterns change slowly, however, and while they must be considered, they usually do not present a major problem unless the multiplier is several years old. The rate of growth in the local area will influence the period of use for the multipliers.

(6) What can a multiplier do? As are most multipliers encountered by local decision makers, the multipliers discussed here are static in nature. Static means that a multiplier can be used in "if/then" situations; they do not project the future. For example, if a new mine that employs 500 people comes into the country, then the total employment increase would be the employment multiplier times 500. A static model cannot be used to make projections about the time needed for an impact to run its course, or about the distribution of the impact over time. Static multipliers only indicate that if X happens, then Y will eventually occur.

(7) How large is the impact in relation to the size of the affected industry on which the multiplier is based? Dramatic changes in an industry's scale will usually alter markets, service requirements, and other components of an industry's spending patterns. Assume a mining sector employment multiplier of 2.0 had been developed in a rural economy having 132 FTE. If a mine were proposed several years later with an estimated 300 FTE, the multiplier of 2.0 would probably not accurately reflect the change in employment because of the scale of the project relative to the industry existing when the multiplier was developed. In essence, the new industry would probably change the existing economic structure in the local area.

(8) Who calculated the multiplier—and did the person or agency doing the calculation have a vested interest in the result? Multipliers are calculated by people using statistics, and as such, there is always the opportunity to adjust the size of the multiplier intentionally. Before accepting the results of a given multiplier, take time to assess the origin of the data. Studies conducted by individuals or firms having a vested interest in the study's results deserve careful examination.

(9) Is household income included as a sector similar to the business sectors in the local economic model? The decision to include household income in the model depends upon whether or not the household sector is expected to react similarly to other sectors when the economy changes, or whether personal income is largely produced by outside forces. Discussion of this issue is too lengthy for this publication, but the important point is that multipliers from models that include household sectors are likely to be larger than those from models without household sectors.