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RESEARCH ARTICLE

Regulatory Restrictions Across U.S. Protein Supply Chains

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Abstract

Food regulations protect consumer health, mitigate environmental concerns, and promote animal welfare, but they can also hinder innovation, limit entrepreneurship, and generate higher consumer prices. This study examines the number of federal and state regulatory restrictions affecting the beef, pork, poultry, sheep, goat, and seafood industries, including processing, wholesale distribution, and retail sales. We also examine state regulatory heterogeneity associated with animal protein products. Our results suggest that protein supply chains have become subject to tens of thousands of regulatory constraints over the past half-century. We also find substantial heterogeneity in the number of state restrictions associated with animal production, indicative of large differences in the amount of administrative law across states. Results highlight that the patchwork approach of U.S. food policy creates overlapping, cumbersome guidelines for manufacturers, and given the interconnectivity of modern food supply chains, the framework can create additional hurdles for interstate commerce.

1. Introduction

Food safety, security, and resilience are the primary objectives of several key government agencies. At the federal level, the U.S. Food and Drug Administration (FDA), the U.S. Department of Agriculture Food Safety Inspection Service (USDA-FSIS), the Environmental Protection Agency (EPA), and Centers for Disease Control and Prevention (CDC) regulate and monitor food safety and production. At the state and local level, there are over 3,000 agencies whose main objective is regulation and oversight of food retail (FDA, 2020). Regulatory constraints—such as mandatory food labeling laws, safety and quality inspections, and establishment licensing—protect consumers, mitigate environmental hazards, and moderate industry and economic growth (Dawson and Seater, 2013), albeit at the risk of unintended consequences (Malone and Stack, 2017) and higher consumer prices (Chambers, Collins, and Krause, 2019).

In this article, we explore regulatory variation across supply chains at the federal and state level for animal protein products, including beef, pig, poultry, sheep, goat, and seafood. We focus on these foods because animal protein makes up nearly 50% of total protein intake in U.S. adults (Pasiakos et al., 2015), and nearly 80% of U.S. adults consume meat as a protein source while 30% consume seafood (Shahbandeh, 2018). Indeed, beef, poultry, and seafood are among the most-consumed protein sources in the United States (USDA-ERS, 2019). Supply chain sustainability and resiliency have been brought to center stage given meat shortages partially driven by

COVID-19 outbreaks at meat-packing plants (Lusk, Tonsor, and Schulz, 2021; Mallory, 2021; Martinez, Maples, and Benavidez, 2021), environmental concerns linking meat consumption to climate change (Hunter and Röös, 2016), and increased consumer sentiment for animal welfare (McKendree, Croney, and Widmar, 2014; Ortega and Wolf, 2018). Indeed, relaxing regulatory restrictions on agricultural systems has been one recommendation for increasing supply chain resiliency (Malone, Schaefer, and Lusk, 2021; Thilmany and Malone, 2020). As such, our objective in this article is to compare regulatory restrictions across animal producer types and industry supply chains.

Many studies examine the effects of regulations in the food sector (Bovay and Alston, 2018; Escalante, Luo, and Taylor, 2020; Mojduszka and Caswell, 2000; Zago & Pick, 2004), but few have explored regulations within an industry across states or across whole supply chains as we do here. Fewer still have sought to compare regulatory constraints *between* industries (Al-Ubaydli and McLaughlin, 2017). To accomplish these tasks, we utilize novel data made available from the Mercatus Center's RegData and State RegData. These databases utilize machine-learning techniques to count instances of words that indicate binding restrictions in federal and state laws. We use these counts and input–output (I–O) modeling to assess the number of regulatory restrictions at the federal level affecting animal producers, as well as the number of federal and state regulatory restrictions affecting animal protein supply chains.

Our contribution to the literature is threefold. First, we complement existing research (Al-Ubaydli and McLaughlin, 2017; Dawson and Seater, 2013; Djankov et al., 2002; Stigler, 1971) by examining the number of federal regulatory restrictions affecting the beef, pig, poultry, sheep, goat, and seafood industries, which reveals the potential for important differences in U.S. animal production regulations. Comparisons across industries allows us to assess calls to reduce regulatory costs in certain industries, for example, aquaculture in the United States (Engle et al., 2019).[1] If regulatory restrictions closely approximate regulatory burden, then one would expect that industries with greater relative concerns about regulatory burden have more regulatory restrictions.[2] Second, we examine the number of regulatory restrictions at the federal level "downstream" of animal producers, including processing, wholesale distribution, and retail sales, to assess the amount of regulation across agricultural supply chains and animal protein sources. Examining regulations across an entire supply chain is important because regulation directed at one part of the chain can affect activity in another part. Third, we examine state regulatory heterogeneity associated with animal protein products by measuring the number of restrictions at the state level. We examine this heterogeneity for animal producers as a whole, without disaggregating by animal type, because of insufficient granularity in the data at the state level. Nevertheless, these results reveal stark differences in the amount of restrictions by state.

In making these contributions, we also seek to introduce a novel dataset to the agricultural economics literature. The restriction counts in RegData offer a number of advantages over other, previously used metrics quantifying regulation at the macrolevel. For example, prior research has used pages published in the *Federal Register* to proxy regulations, except the *Federal Register* includes parts that actually remove regulations and thus make it a poor measure (Al-Ubaydli and McLaughlin, 2017). Other metrics include the size of a statute document or the number

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[1]This particular example is important because increasing U.S. reliance on imports to meet domestic seafood demand has led to concerns among industry stakeholders and policy makers that U.S. aquaculture faces disproportionate barriers to growth (Hyink and Melstrom, 2021). Between 1950 and 2017, U.S. aquaculture production as a share of global output fell from 10% to less than 0.5% (Shamshak et al., 2019), which appears to lend some credibility to these concerns. However, it should also be noted that U.S. aquaculture output in fact nearly tripled between 1980 and 2017 from 168,000 tonnes to 468,000 tonnes, with production peaking in 2004 at over 600,000 tonnes (FAO, 2021a). In contrast, between 1970 and 2018 U.S. beef production increased 25% (USDA-ERS, 2021), and between 1960 and 2006 U.S. broiler production increased nearly 500% (MacDonald, 2008).

[2]The Government Accountability Office (GAO) identifies three basic measures of regulatory burden: indicators (e.g. pages in the Code of Federal Regulations), time (e.g. hours to complete paperwork), and cost (GAO, 1996). For the purposes of this paper, we use burden and cost as synonyms.

of federal employees assigned to regulatory activities (GAO, 1996). Another key advantage to RegData is that the restrictions are an annual, industry-specific panel, which makes it possible to track the accumulation of regulations across industries. In contrast, prior research has tended to rely on cross-sectional proxies (Al-Ubaydli and McLaughlin, 2017). RegData covers the *Code of Federal Regulations* (CFR) from 1970 to 2019, so we can use the restriction counts to assess relative changes in animal protein industry regulations over nearly a half century.

The remainder of this article is structured as follows. In Section 2, we provide background on food regulations and the CFR. Section 3 introduces the methodology used to quantify regulatory restrictions across supply chains. In Section 4, we present the results, and Section 5 discusses these results. Section 6 concludes.

2. Background

From the onset of U.S. food safety standards and regulations, most meat products have been regulated differently than other food products. The first major federal food policy initiatives were the Pure Food and Drug Act of 1906 and the Meat Inspection Act of 1906. Whereas the Pure Food and Drug Act established the U.S. Food and Drug Administration (FDA) and gave the agency overarching authority to regulate food products, the Federal Meat Inspection Act—signed into law the same day—gave the USDA the jurisdiction to inspect cattle, hog, poultry, sheep, and goat slaughtering and processing (Fortin, 2017).

Advancements in refrigeration technology shifted consumption patterns and raised the standard of living in the United States, leaving the Pure Food and Drug Act obsolete shortly after it was passed. In 1938, Congress passed the Food, Drug, and Cosmetic Act (FD&C Act) of 1938, which still serves as the foundation for food law. The FD&C Act has been amended over 100 times since it was passed in 1938 (Fortin, 2017), with the most significant amendment being the Food Safety Modernization Act (FSMA) of 2011. The FSMA offered seven substantial changes to the FD&C Act of 1938, including measures to prevent foodborne outbreaks, subdue intentional adulteration of food products, and improve sanitary transportation requirements (Strauss, 2011; Thatte, 2019). Other significant amendments to the FD&C Act include the Food Additive Amendment of 1958, the Color Additive Amendment of 1960, and the Nutritional Labeling and Education Act of 1990 (Fortin, 2017).

The Federal Meat Inspection Act of 1906 has also been amended significantly. Most notably, the Wholesome Meat Act of 1967 was introduced to prevent the adulteration and misbranding of meat products and to ensure the slaughter and processing of meat and meat products occurred in sanitary conditions (Fortin, 2017). Additional food policies governing the regulation of the meat industry include the Poultry Products Inspection Act of 1957, the Egg Products Inspection Act of 1970, and the Humane Methods of Livestock Slaughter Act of 1978 (USDA-FSIS, 2016).

Importantly, while most cattle, hog, poultry, egg, sheep, and goat products are regulated by the USDA-FSIS, aquaculture and seafood fall predominantly under the FDA's jurisdiction; and the FDA is currently a sub-division of the Department of Health and Human Services (HHS)—not the USDA-FSIS. Thus, while the overarching goals of the FDA and USDA-FSIS are nearly identical, aquaculture is subject to different regulations than most other protein sources. In other words, amendments made to the FD&C Act affect the aquaculture industry, but do not directly restrict the other meat industries, for which amendments must be made to the USDA-FSIS policies (e.g., Federal Meat Inspection Act). In addition, the regulatory jurisdiction does not always fall entirely on one agency. Indeed, the overlapping framework may be intentional, mitigating regulatory loopholes and capturing the decentralized expertise amongst various agencies. For example, in addition to regulation from the FDA under the Department of HHS, the aquaculture industry is regulated by the USDA, the EPA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fisheries and Wildlife Service (FWS), the Animal and Plant Health Inspection Service (APHIS), and others (FAO, 2021b).

It is also critical to summarize how statutes passed by Congress and signed into law by the President are converted into the regulations. When federal policy is signed into law, the statutes are codified into the *United States Code*. These statutes are then announced as regulations, subject to the interpretation of the federal agency with presiding jurisdiction. These regulations must then be codified into the CFR. However, prior to final publication of the regulations, an initial ruling is published in the *Federal Register*. The initial ruling outlines the agency's interpretation of the statute and describes the rules, protocols, and procedures for compliance. Once the initial ruling is posted, industry stakeholders and the general public are given notice of the proposed regulations. There is then a period for comment and clarification, after which the initial ruling is revised. Following revisions, the final ruling is published, an effective date is declared, and the regulation is officially codified in the CFR. Thus, while the statutes receive significant media attention when they are signed into law, codifying the regulations enforcing these statutes into the CFR can take several years.

In addition to federal laws enacted by Congress and the regulations authorized by these administrative agencies, states can legislate food policy. This authority is generally granted under the *police powers* provided to states by the Federalist system (Fortin, 2017), which ensures states are allowed to enact legislation to protect consumer health and welfare. However, state laws may be deemed unconstitutional if they interfere with interstate commerce, an authority given to the federal government (Sumner, 2017). In other words, if the state policy is shown to affect the production, distribution, or market prices outside of the state, the policy could be struck down by the courts (Fortin, 2017). Legal battles over policies such as California's Assembly Bill 1437 for cage-free eggs (Carter, Schaefer, and Scheitrum, 2021) and Vermont's call for mandatory labeling on genetically engineered food (Kolodinsky and Lusk, 2018) have reinvigorated the discussion surrounding the Commerce Clause. Nonetheless, since states have the ability to enact legislation on health, safety, and consumer welfare as it relates to food, food regulations are likely to vary across state borders.

The federal policies regulating food systems are complex and interconnected in an effort to protect the consumer and prevent regulatory loopholes. Further, state and local governments may regulate food systems more stringently than the federal government. Thus, there is significant merit in understanding the evolution of regulations as they pertain to food systems, comparing regulations across different supply chains, and examining the heterogeneity in regulations at the state level.

3. Data and Methods

We measure regulatory restrictions as the accumulation of words in federal and state law that indicate restrictions and requirements in a particular industry. Within the scope of our analysis, these "regulatory restrictions" come from two datasets of industry-specific regulations produced by the Mercatus Center: State RegData 2.0, and RegData 3.2. State RegData 2.0 counts each instance of a binding restriction that appears in the published rules and guidelines contained in the laws of 43 states plus the District of Columbia. RegData 3.2 is very similar, except that it counts each instance of a binding federal restriction that appears in the U.S. CFR. Each time a word indicating a restriction or requirement appears in the regulatory text (i.e. the words shall, must, may not, prohibited, and required), that word is counted as a regulatory restriction. RegData 3.2 also contains an index of restrictions at the four-digit North American Industry Classification System (NAICS) level, constructed by multiplying the number of restrictive words by a measure of industry relevance. Industry relevance is itself measured using a machine-learning algorithm trained on industry-specific publications in the *Federal Register*, which includes documents labeled with the relevant NAICS code and a writing style similar to the CFR. The algorithm identifies words, phrases, and other document features most closely associated with an industry's NAICS code or name, which helps determine when a unit of text is relevant to an industry.

The association between a NAICS industry and document features is modeled using a logistic function. When applied to the CFR, this function calculates the probability that a federal law is relevant to a NAICS industry. Regulatory restrictions are thus probability-weighted by their industry relevance and summed by industry. For further details on the methodology of calculating restrictions and industry relevance, see McLaughlin & Sherouse (2019).

The restriction counts in RegData offer a number of advantages over previously used metrics quantifying regulation at the macro level such as counting the total number of pages published in the *Federal Register* to proxy regulations, examining the size of a statute document, or calculating the number of federal employees assigned to regulatory activities (Al-Ubaydli and McLaughlin, 2017; GAO, 1996). Further, RegData provides an annual, industry-specific panel rather than a cross-sectional proxy, allowing researchers to track the accumulation of regulations across industries. RegData covers the CFR from 1970 to 2019, so we can use the restriction counts to assess relative changes in animal protein industry regulations over the past half-century.

Using RegData, we examine the accumulation of federal regulatory restrictions down the animal production industry's value chain. We mean "downstream" in the sense that processed animal protein is an intermediate input that increases in value (as measured by wholesale and retail margins) as it moves through the value chain from the rancher or farmer to the consumer. We refer to the restrictions associated with these activities as *direct restrictions*.

We calculate direct restrictions at the federal level in six animal protein industries: cattle ranching and farming, hog and pig farming, chicken and egg production, sheep and goat farming, aquaculture, and other animal production. These industries correspond to NAICS codes 1121, 1122, 1123, 1124, 1125, and 1129, respectively. We then calculate direct restrictions in the animal processing, wholesale distribution, and retail sales industries, which correspond to NAICS codes 311X (which includes sectors 3116 and 3117), 4244 and 4451, and through which most animal protein products pass before reaching consumers. This is similar to the approach of Malone and Chambers (2017), who measured federal regulatory restrictions that apply to both the three-tier beer distribution system (i.e., brewing, wholesale distribution, and retail distribution). In a follow-up study using a similar methodology, Staples et al. (2021) extended this analysis to the regulations promulgated by individual states, using State RegData to measure state regulatory restrictions that apply to both the beer value chain and the inputs needed to produce these goods and services.[3] This article expands on this methodology to study regulations in animal protein production, counting direct restrictions across four-tier animal protein distribution systems (i.e. production, processing, wholesale distribution, and retail sales).

It is also possible to use RegData to estimate the "upstream" regulations that apply to an industry's supply chain. We refer to these as *indirect restrictions* because they affect inputs to animal production rather the animal producers or processors themselves. Following Chambers et al. (2019),[4] Malone and Chambers (2017), and Staples et al. (2021), we calculate upstream regulations using I–O commodity weights from the Bureau of Economic Analysis (BEA) to weight the regulatory restrictions that apply to each industry that produces the inputs required by that industry's supply chain. Specifically,

$$\text{Reg}_{j,t}^{\text{indirect}} = \sum_i \alpha_i \cdot \text{Reg}_{i,t}^{\text{direct}} \tag{1}$$

estimates the total indirect federal restrictions that apply to industry j (i.e., animal protein production, processing, wholesale or retail distribution) in year t; i is the index of supply chain industries that supply inputs to industry j; α_i are I–O commodity weights from the BEA renormalized to sum to one; and $\text{Reg}_{i,t}^{\text{direct}}$ are the direct federal restrictions for industry i in year t as reported by RegData.

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[3]Staples et al. (2021) find significant heterogeneity in regulation restrictions in the beer industry across states, but they do they do not compare changes in industry-specific regulatory restrictions over time and across industries as we do here.

[4]Chambers et al. (2019) was first presented as a working paper by the Mercatus Center 2016.

Next, we use State RegData and the input-output parameters to estimate the number of direct and indirect restrictions at the state level. The granularity of the industry regulation data provided by State RegData is limited to the NAICS three-digit level. We therefore use NAICS code 112 ("animal production and aquaculture"), which aggregates the four-digit industries of interest. State RegData is limited to regulations in 2020 only. Thus, all of the state-level regulations are limited to the aggregate animal production industries in 2020. The state indirect restrictions that apply to industry j (i.e., animal protein production, processing, wholesale, or retail distribution) in state h are

$$\text{Reg}_{j,h}^{\text{indirect}} = \sum_i \alpha_i \cdot \text{Reg}_{i,h}^{\text{direct}} \qquad (2)$$

where i is the index of industries that supply inputs to industry j; α_i are the I–O commodity weights; and $\text{Reg}_{i,h}^{\text{direct}}$ are the direct state restrictions for industry i in state h as reported by State RegData. For the sake of comparison, we also estimate the direct and indirect federal restrictions of all animal production and aquaculture (NAICS 112) as of 2019.

The BEA data are derived from the economic census (latest data are from 2012; see BEA, n.d.b) and are reported as "The Use Table (Supply-Use Framework), 2012," which records the dollar value of inputs from private and public entities and industries used as intermediate inputs to produce the output of an industry.[5] After removing inputs from all non-private sector industries (i.e., federal, state, and local government enterprises)[6] that provided less than 1.11% of all inputs, we normalized the remaining inputs to add to one (i.e. expressed as value-weighted inputs).[7] Each industry's final inputs weights, α_i, are presented in the Appendix accompanying this manuscript.[8]

Regulatory restrictions should be interpreted as a proxy rather than a full measure of regulatory cost. Counting restrictions provides no information on the intensity of a particular regulation, which could be restrictive or lax in practice. For example, our approach treats a regulation stating "the maximum line speed is 1,106 pigs per hour" as equivalent to a regulation stating "the maximum line speed is 2,212 pigs per hour," even though the former is more restrictive than the latter.[9] Due to the paucity of research tying measures of regulations to actual regulatory costs, it is not possible to measure how closely regulatory restrictions correlate with regulatory burden. However, research on RegData finds that the number of restrictions declines in industries going through a period of deregulation, including air transportation and the Airline Deregulation Act of 1978, which shows that regulatory restrictions parallel actual regulatory trends and, by implication, regulatory costs (Al-Ubaydli and McLaughlin, 2017).

4. Results

Table 1 presents the number of direct restrictions at the federal level over time. Column one presents the regulatory year, columns two through seven correspond to the individual production

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[5]The data can be obtained from https://www.bea.gov/industry/input-output-accounts-data#tab-02 by clicking on Use Tables (Use of commodities by industry) for 2007, 2012 detailed (405) industries (https://apps.bea.gov/industry/xls/io-annual/Use_SUT_Framework_2007_2012_DET.xlsx). The dollar value of intermediate inputs from private and public entities and industries to produce the output of an industry are reflected in the columns of the table.

[6]The BEA defines government enterprises as "Government agencies that cover a substantial portion of their operating costs by selling goods and services to the public and that maintain their own separate accounts" (BEA, n.d.a).

[7]RegData does not estimate regulations that pertain to public sector entities, so the scope of input activity is restricted to non-public sector entities. Moreover, the only government sectors providing inputs to our five industries were the U.S. Postal Service and "other state and local government enterprises." In 2012, these public input sectors represented approximately 0% of the intermediate inputs for beef, poultry, and aquaculture production, 3.17% of the intermediate inputs for wholesale distribution, and 0.98% of the intermediate inputs for retail sales.

[8]The BEA does not directly report input weights for NAICS sector 1125, but instead provides I-O data for BEA industry code 112A (Animal production, except cattle and poultry and eggs), which comprise NAICS sectors 1122, 1124, 1125, and 1129.

[9]We would like to acknowledge the contributions of a reviewer in raising this point.

Table 1. Number of direct restrictions across animal protein value chains

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Process-ing	Wholesale	Retail sales
NAICS	1121	1122	1123	1124	1125	1129	311X	4244	4451
1970	558	1,194	790	1,072	6,852	1,482	3,436	555	3,034
1979	1,432	2,584	2,885	2,245	8,276	2,211	4,400	1,130	3,904
1989	1,793	3,029	4,691	2,882	17,240	2,915	5,704	2,235	5,521
1999	2,653	4,345	4,646	4,145	24,902	3,567	6,401	2,648	7,220
2009	3,699	5,222	5,608	5,226	32,435	4,458	8,685	4,612	7,896
2019	3,761	6,505	6,256	6,511	48,843	5,323	12,149	5,027	11,839

Note: Yearly federal direct regulatory restrictions for each industry are presented in Table A2 of the Appendix accompanying this manuscript.

industries, and columns eight through ten present the number of downstream restrictions in the processing, wholesale, and retail sales industries, respectively. These estimates show that in 1970, cattle ranching was subject to 558 direct restrictions, 1,194 restrictions in hog and pig farming, 790 restrictions in poultry and eggs, 1,072 restrictions in sheep and goat farming, 6,852 restrictions in aquaculture, and 1,482 restrictions in other animal production. In 2019, there were 3,761 direct restrictions in cattle ranching, 6,505 restrictions in hog and pig farming, 6,256 restrictions in poultry and eggs, 6,511 restrictions in sheep and goat farming, 48,843 restrictions in aquaculture, and 5,323 restrictions in other animal industries. Thus, between 1970 and 2019, the estimated number of direct restrictions increased substantially in every production industry. If we pool industries based on three-digit NAICS codes to reduce double-counting regulations, then over this period regulatory restrictions in animal protein value chain increased 330%.

The largest change in regulatory restrictions occurred in the aquaculture industry. We find an increase of more than 40,000 regulations between 1970 and 2019, more than a 600% increase. Additionally, aquaculture has the largest share of federal direct restrictions, and this share is growing. Figure 1 shows direct restrictions in each production industry as a share of the total number of regulations across all six industries. As the figure illustrates, since 1970, on average, more than 50% of direct restrictions associated with animal protein production can be linked to aquaculture, and since 2017 the share linked to aquaculture has exceeded 60%.

There are also important relative changes among the other industries. Focusing on producers, the largest proportional increase—nearly 700%—in direct regulations between 1970 and 2019 is associated with poultry. Downstream, however, direct regulations associated with wholesale distribution increased 800%. Thus, when considering the entire value chain, federal direct regulations increased the most in the wholesale industry.

These trends change little when assessed in terms of the total number of regulatory restrictions, including direct and indirect regulations. Table 2 presents the total number of regulatory restrictions at the federal level for each industry, while Figure 2 plots the changes in restrictions over time for each of the six animal industries (four-digit NAICS code).

In general, total regulatory restrictions follow similar patterns of regulation and deregulation across industries over time. For instance, each industry sees significant increases—as much as a 25% increase year-over-year—in regulatory restrictions in 2017, coinciding with the final rulings on Mitigation Strategies to Protect Food Against Intentional Adulteration (21 CFR 11; 21 CFR 121) and Sanitary Transportation of Human and Animal Food (21 CFR 11), two components of the FDA Food Safety Modernization Act passed in 2011.[10] As before, the largest overall increase

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[10]The final ruling for Mitigation Strategies to Protect Food Against Intentional Adulteration (21 CFR 121) was published on May 27, 2016. The final ruling for Sanitary Transportation of Human and Animal Food (21 CFR 11) was published on April 6,

Table 2. Total number of direct and indirect restrictions across animal protein value chains

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Process-ing	Wholesale	Retail sales
NAICS	1121	1122	1123	1124	1125	1129	311X	4244	4451
1970	7,726	8,905	9,651	8,783	14,563	9,194	12,451	5,730	8,133
1979	11,433	12,733	13,717	12,395	18,425	12,361	16,141	11,893	13,991
1989	15,715	16,987	17,830	16,840	31,198	16,873	22,012	18,189	20,483
1999	21,889	23,380	21,094	23,180	43,936	22,602	27,708	21,659	25,037
2009	25,108	25,553	20,645	25,557	52,766	24,789	30,871	26,560	28,149
2019	36,515	37,435	26,526	37,441	79,773	36,253	47,757	31,732	38,742

Note: Yearly federal direct and indirect regulatory constraints for each industry are presented in Table A3 of the Appendix accompanying this manuscript.
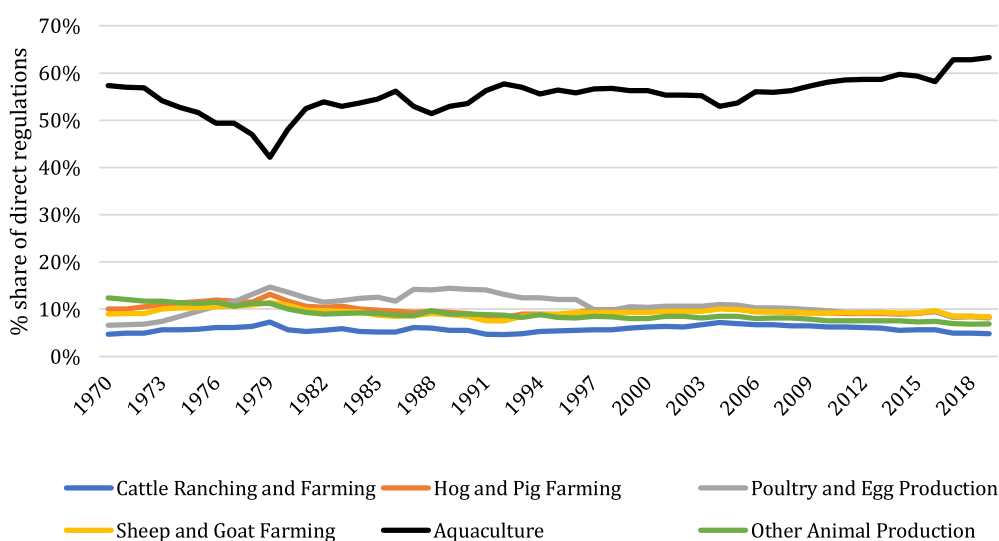
Figure 1. Estimated share of direct restrictions in federal law in different animal protein industries.

in restrictions across the 50-year period is associated with aquaculture, although there is also a large relative change in the wholesale industry. However, the relative increase in restrictions associated with poultry is less pronounced than before, which indicates that indirect restrictions associated with poultry production have changed relatively little over the period of study. In contrast, the relative increase in restrictions associated with aquaculture is greater than before, which indicates that indirect restrictions associated with aquaculture production have increased more than restrictions in some other production industries (e.g. poultry).

2016. According to the Code of Federal Regulations (Annual Addition) (n.d.), the CFR annual addition codifies the 50 subject matter titles following a staggered schedule. Titles 1-16 are revised January 1; Titles 17-27 are revised as of April 1; Titles 28-41 are revised as of July 1; and Titles 42-50 are revised as of October 1. As Mitigation Strategies to Protect Food Against Intentional Adulteration was published in the CFR May 27, 2016 and Sanitary Transportation of Human and Animal Food was published April 6, 2016, the annual addition does not reflect the change to Title 21: Food and Drugs until April 1, 2017. Hence, these food policy initiatives are captured in the 2017 federal regulatory restrictions.
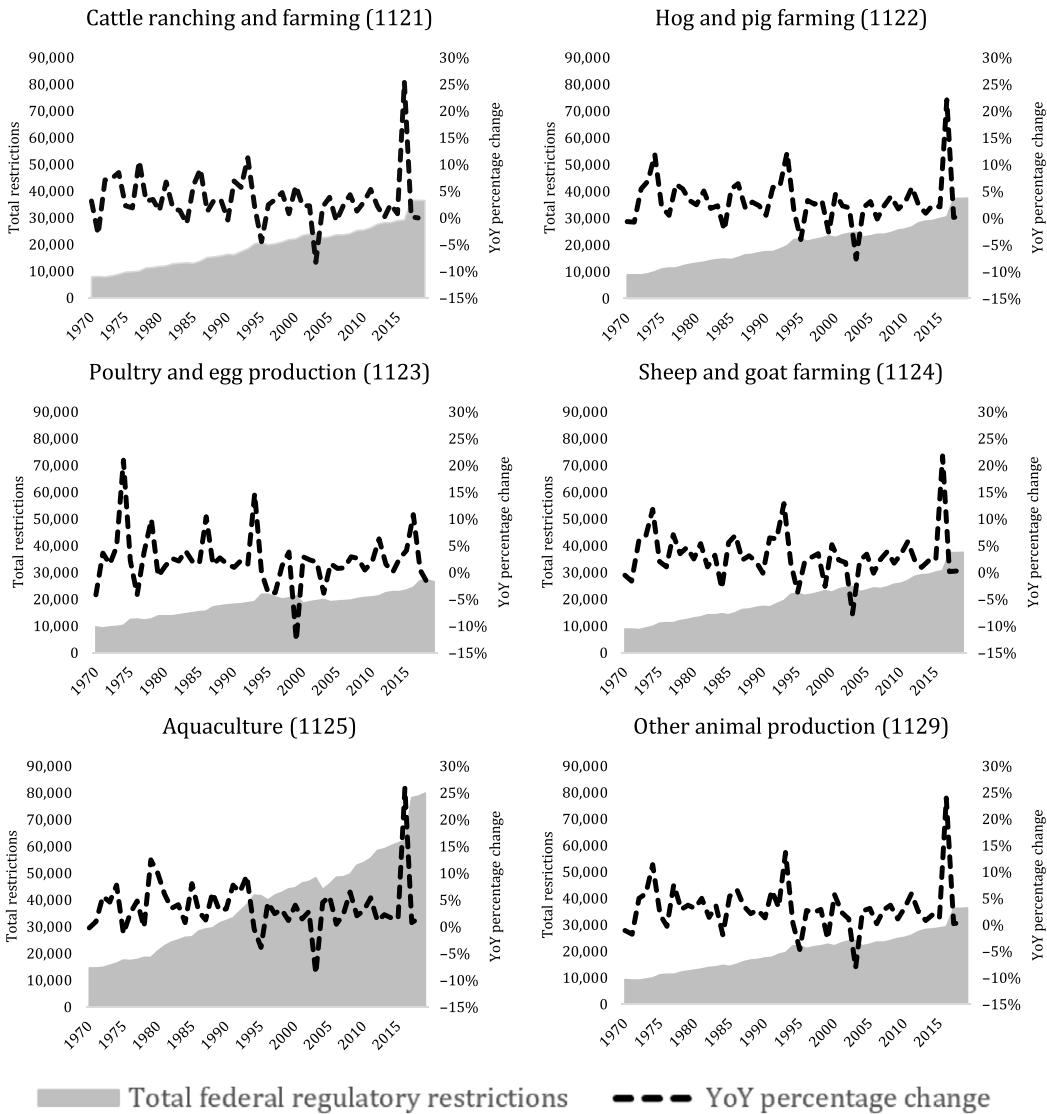
Figure 2. Regulatory restrictions by animal industry (four-digit NAICS) over time and year-over-year (YoY) percentage change by industry.

Considering restrictive regulatory language at the state level, Table 3 presents the number of direct restrictions associated with animal production, animal processing, wholesale distribution, and retail sales. Recall, we cannot estimate the direct restrictions in each production industry (e.g. cattle ranching, pigs, and poultry) because State RegData only records regulatory restrictions at the three-digit NAICS level, while the production industries are at the four-digit level. The estimates thus provide a sense of the variability in direct restrictions associated with animal production at the state level, which appears to be substantial. Table 3 shows that the number of direct restrictions associated with all animal production ranges from a low of 64 to a high of 12,324—a relative difference of nearly 2,000%. The average is 3,939, with a standard deviation of 2,199. There is modest correlation between the number of direct restrictions associated with animal production and the numbers associated with animal processing

Table 3. Number of direct regulations by industry (3-digit NAICS code) at the state and federal level

	All animals	Processing	Wholesale	Retail sales	Total
NAICS	**112**	**311**	**424**	**445**	
Alabama	4,408	390	156	1,684	6,639
Arizona	1,181	54	251	351	1,837
California	8,052	2,416	555	5,753	16,775
Colorado	6,822	529	306	1,399	9,056
Delaware	3,777	399	799	4,249	9,225
District of Columbia	1,114	501	893	1,654	4,162
Florida	5,951	927	636	4,773	12,286
Georgia	2,641	2,611	152	3,093	8,497
Idaho	3,098	144	151	352	3,744
Illinois	8,000	494	519	7,970	16,983
Indiana	3,808	115	129	1,023	5,075
Iowa	4,516	611	194	2,697	8,019
Kansas	1,044	242	204	1,092	2,582
Kentucky	1,269	1,734	257	1,785	5,046
Louisiana	8,033	628	124	5,003	13,787
Maine	5,601	1,900	475	2,273	10,249
Maryland	1,984	583	259	1,376	4,201
Massachusetts	3,781	639	546	6,657	11,623
Michigan	2,852	941	212	844	4,850
Minnesota	3,668	1,842	238	1,826	7,574
Mississippi	3,624	744	119	1,582	6,069
Missouri	1,265	421	129	649	2,465
Montana	3,472	528	123	411	4,534
Nebraska	1,650	364	242	849	3,105
Nevada	1,648	172	191	858	2,870
New Hampshire	3,421	701	367	2,162	6,650
New York	3,400	4,120	531	6,495	14,546
North Carolina	4,395	272	350	2,286	7,303
North Dakota	64	272	46	453	834
Ohio	4,183	1,942	288	2,195	8,608
Oklahoma	4,663	1,386	224	2,236	8,509
Oregon	12,324	1,210	422	3,934	17,890
Pennsylvania	1,161	2,173	239	2,077	5,651
Rhode Island	9,035	524	489	1,078	11,126
South Carolina	2,626	1,044	444	3,301	7,416

(*Continued*)

Table 3. (*Continued*)

	All animals	Processing	Wholesale	Retail sales	Total
South Dakota	383	457	27	100	967
Tennessee	1,310	813	221	2,844	5,188
Texas	4,031	963	2,598	4,823	12,415
Utah	3,066	392	289	1,103	4,851
Virginia	3,994	856	208	4,865	9,924
Washington	10,717	1,528	753	4,941	17,938
West Virginia	2,968	868	195	1,680	5,709
Wisconsin	6,162	1,757	292	2,648	10,860
Wyoming	2,135	241	189	1,112	3,677
U.S. federal (2019)	44,757	22,903	5,027	11,839	84,526

($\rho = 0.186$), wholesale distribution ($\rho = 0.211$), and retail sales ($\rho = 0.525$), which implies that states with a relatively large number of direct regulations in one industry tend to have relatively more regulations overall. This pattern of heterogeneity suggests important differences in how states have written their laws. Generally, these differences are less pronounced between neighboring states and correlate with population and the level of economic activity. For example, South and North Dakota have the lowest numbers of direct regulations associated with animal production, compared to Oregon, Washington state, and California with the highest numbers.

Table 4 presents the total (direct and indirect) restrictions by industry (3-digit NAICS code), and Figure 3 presents these results graphically. The range of total restrictions associated with animal production is between 715 (North Dakota) and 18,010 (Oregon); between 885 (North Dakota) and 21,570 (Oregon) for processing; between 246 (South Dakota) and 8,221 (Texas) for wholesale; and between 325 (South Dakota) and 12,234 (Illinois) for retail. The estimates reveal that states with a lower number of direct regulations tend to have fewer total regulations. Indeed, if we ranked states by regulatory restrictions associated with animal production, the rankings would change little if we used direct rather than total restrictions, as there is a high degree of correlation between direct and indirect restrictions ($\rho = 0.983$). Setting aside animal processing, for which animal production is a key input, the total number of regulatory restrictions associated with animal production is greater than that of wholesale distribution and retail sales. Further, 73% of states in our data set (32 of 44 jurisdictions) have more restrictions associated with animal production than wholesale and retail sales. However, there are more total regulatory restrictions associated with animal processing than any of the other three-digit industries, although this is driven mainly by indirect restrictions.

Our estimates indicate a larger number of restrictions at the federal level than at the state level. The last row of Tables 3 and 4 include the estimates of direct and total restrictions at the federal level for each of the three three-digit NAICS industries, respectively. In every industry category, the number of federal restrictions exceeds the number of restrictions in any state, including direct and total restrictions.

5. Discussion

The result that direct restrictions associated with the animal protein value chain have increased by more than a factor of three needs to be taken in context. When computed on an annualized basis,

Table 4. Number of total direct and indirect restrictions by industry (3-digit NAICS code) at the state and federal level

	All animals	Processing	Wholesale	Retail sales	Total
NAICS	112	311	424	445	
Alabama	6,719	7,594	1,532	2,791	18,636
Arizona	1,996	2,192	994	1,005	6,188
California	13,269	19,486	6,921	11,992	51,668
Colorado	10,469	12,220	3,953	4,366	31,008
Delaware	6,253	7,118	2,920	6,164	22,455
District of Columbia	1,940	2,880	2,391	2,855	10,066
Florida	9,127	10,847	2,608	6,561	29,142
Georgia	5,172	8,750	3,054	5,455	22,431
Idaho	4,471	5,076	775	932	11,255
Illinois	12,607	14,416	4,978	12,234	44,234
Indiana	5,699	6,816	1,486	2,218	16,218
Iowa	6,964	8,429	2,302	4,625	22,320
Kansas	1,783	2,400	1,170	1,978	7,331
Kentucky	2,666	5,397	1,401	2,912	12,376
Louisiana	12,104	13,700	2,463	7,061	35,327
Maine	8,771	12,171	3,171	4,586	28,698
Maryland	3,294	4,443	1,853	2,739	12,329
Massachusetts	6,066	8,124	3,886	9,655	27,731
Michigan	4,749	6,361	1,531	2,280	14,921
Minnesota	6,347	9,134	2,114	3,748	21,344
Mississippi	5,852	7,922	3,405	4,291	21,470
Missouri	2,214	3,221	1,692	2,052	9,179
Montana	5,388	6,391	1,181	1,541	14,501
Nebraska	2,634	3,575	1,742	2,164	10,115
Nevada	2,511	3,100	988	1,705	8,303
New Hampshire	5,430	7,395	4,020	5,113	21,958
New York	6,990	13,570	5,218	10,986	36,764
North Carolina	6,711	7,570	1,835	3,718	19,834
North Dakota	715	885	793	1,091	3,484
Ohio	6,909	10,261	2,657	4,357	24,184
Oklahoma	7,435	10,071	2,897	4,831	25,234
Oregon	18,010	21,570	4,317	7,477	51,374
Pennsylvania	2,779	5,966	1,742	3,520	14,006
Rhode Island	12,895	14,857	2,261	2,669	32,683
South Carolina	4,653	6,474	2,062	4,750	17,938

(*Continued*)

Table 4. (*Continued*)

	All animals	Processing	Wholesale	Retail sales	Total
South Dakota	779	1,407	246	325	2,757
Tennessee	2,944	4,122	2,087	4,441	13,594
Texas	7,003	9,936	8,221	9,935	35,096
Utah	4,939	5,856	1,957	2,538	15,290
Virginia	7,096	8,670	3,614	7,975	27,355
Washington	16,184	19,720	4,677	8,721	49,302
West Virginia	4,843	6,647	1,806	3,365	16,661
Wisconsin	10,234	13,760	2,696	4,946	31,636
Wyoming	3,281	4,284	1,635	2,371	11,570
U.S. federal (2019)	73,122	108,045	31,732	38,742	251,640

this result implies a 3% per year increase in direct restrictions across the value chain. This exceeds the increase in overall regulatory restrictions in the CFR since the 1970s, which have grown about 2% per year, although it is lower than the increase in EPA-related regulations, which have grown 5% per year (McLaughlin and Sherouse, 2019). Nevertheless, there can be substantial variation in regulation growth between individual industries, and comparison with prior research suggests that regulation in the animal protein value chain as a whole is intensifying faster than in many other industries (Al-Ubaydli and McLaughlin, 2017; Malone and Chambers, 2017). Moreover, by breaking down regulatory restrictions by industry sector, our results show that restrictions are growing fastest in the wholesale distribution, poultry, and aquaculture industries, while restrictions associated with animal processing and retail sales growing at rates closer to the overall average.

The results reveal differences in the numbers of regulatory restrictions at the federal level associated with animal production industries, numbers that appear relatively modest in the context of one exceptionally striking case. The number of federal restrictions has risen steadily since 1970, across all animal production industries, which likely reflects a general increase in the body of federal law with ties to agriculture and food production. Between cattle ranching, pig farming, poultry and egg production, sheep and goat farming, and other animal industries, there are an estimated 3,701–6,511 direct restrictions, depending on the industry, as of 2019. These differences may be important, but they appear modest when compared to an estimated 48,843 direct regulations associated with aquaculture in 2019. Indeed, we find that for nearly the last half a century, the number of direct and total regulations associated with aquaculture has been approximately double the number of regulations in the other five: cattle ranching, pig farming, poultry and egg production, sheep and goat farming, and other animal industries.

These estimates lend credibility to calls to reduce regulatory costs in aquaculture (Engle et al., 2019). In federal law, more regulatory restrictions are associated with aquaculture than with other industries, including downstream industries associated with consumer safety (i.e., retail sales) and animal production industries that, like aquaculture, have raised concerns about environmental impact (e.g. poultry and egg production). The disparity in these estimates is consistent with claims by some aquaculture industry stakeholders and public officials that overlapping federal agency responsibilities make aquaculture regulations difficult to navigate. While we lack the data to investigate whether this is also true for aquaculture at the state level, we do, however, find evidence that state law has more regulatory language associated with animal production as a whole industry than with wholesale distribution and retail sales, which suggests that regulations at the state level could still disproportionately affect animal producers (including aquaculture) more than is

Panel A. Animal Production (112)
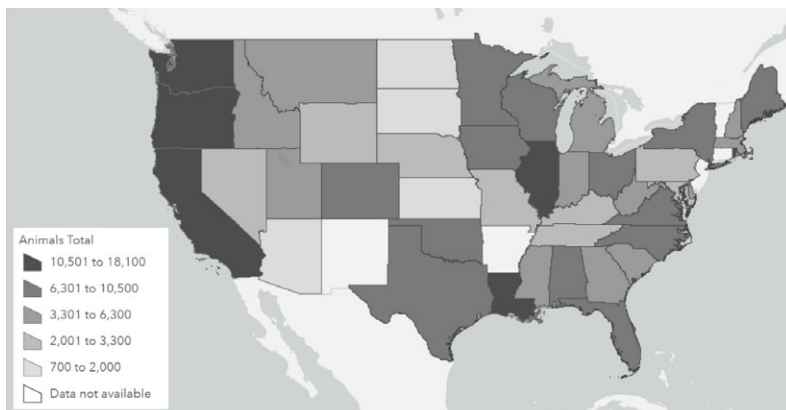
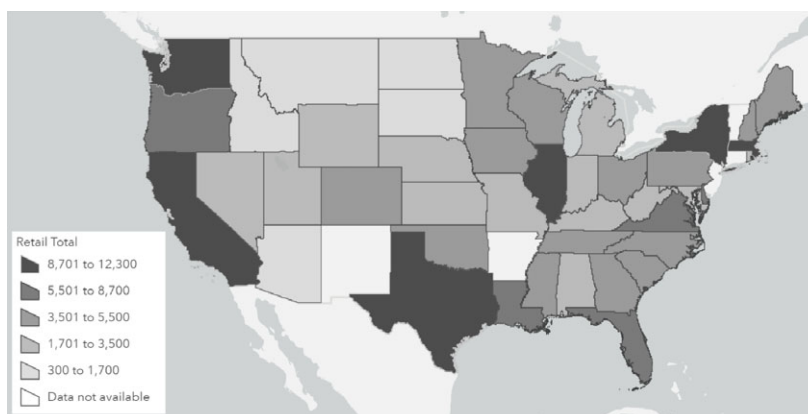Panel B. Wholesale (424)
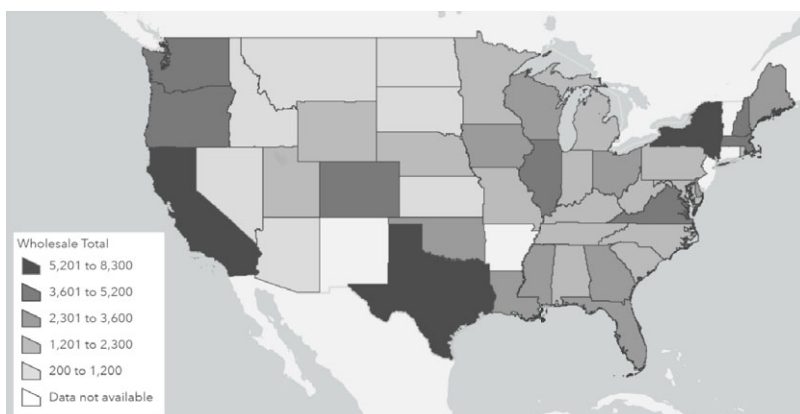
Panel C. Retail (445)

Figure 3. Total direct and indirect regulatory restrictions by industry (3-digit NAICS code) by state.

generally the case with other industries. However, the relative differences between industries at the state level are smaller than the relative difference between aquaculture and other industries at the federal level.

One explanation for additional regulation of aquaculture is the industry's reliance on large amounts of water and varied sources of pollution risk. In the United States, water pollution regularly tops the list of public concerns (Sheth, 2019), putting continuous pressure on federal policy makers to develop and revise laws to limit and clean up sources of wastewater. Aquaculture can affect water quality through discharges of fish manure, feed waste, antibiotics, and outbreaks of fish disease. Fish can be raised in near-shore, pond, flow-through, and tank-based production systems, each of which can come with a unique set of water quality concerns and controls, and thus contribute to a larger and more complex of set of regulations than those experienced by other livestock operations. Indeed, research finds water quality regulations create among the most salient regulatory costs in the aquaculture industry (Engle et al., 2019). A related explanation for additional regulation of aquaculture is that in addition to the FDA and the USDA, which monitors compliance with animal production laws, aquaculture with point-source discharge is subject to monitoring by the EPA and marine aquaculture is subject to monitoring by the NOAA. Put simply, the greater number of restrictions associated with aquaculture could be due to a mix of environmental and food law.

Our results also indicate that a large number of regulatory restrictions at the state level can potentially affect production and distribution of animal products. Including direct and indirect regulations, there are, on average, several thousand state restrictions associated with animal production, as well as with animal processing, wholesale distribution, and retail sales. However, these results do not imply that states with more restrictions are worse off in terms of production. In fact, comparing cash receipts in various animal production sectors with direct restrictions at the state level, we find correlations close to zero.[11] This insight may have important implications for our estimates of federal restrictions, because the differences in restrictions between states are generally larger than the estimates of federal restrictions between industries. The states with the most restrictions have many thousands more restrictions than the states with the fewest. Explaining these differences goes beyond the scope of this article, but the number of regulatory restrictions clearly correlates with the amount of economic activity in a state.[12] Thus, we think much of the heterogeneity in regulatory restrictions is tied to legislatures' responses to increasingly complex state economies.

Of course, our estimates of state-level restrictions up and down the value chain should be interpreted carefully. Thousands of regulatory restrictions affect production of beef, pigs, chickens, and other animals, and the number of these restrictions vary greatly by industry and state. Among the sectors we examined, at the federal level, aquaculture appears to be the most regulated. However, as noted above, regulatory restriction counts do not definitively indicate that certain industries or states may be "overregulated" or insufficiently regulated. To highlight this point by way of example, we compare estimates of total regulations associated with animal production in Michigan and Missouri: there are more than twice as many regulations in Michigan (2,852) than in Missouri (1,265) as well as more regulations associated with wholesale distribution and retail sales in Michigan; yet compared with Michigan, Missouri is not considered to have a better regulatory environment. In fact, at least one ranking places Michigan at the top in terms of regulatory relief (Ruger and Sorens, 2009). Thus, the large number of federal restrictions associated with

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[11]The correlation between the number of direct restrictions in the animal production and 2019 cash receipts in meat, cattle and poultry production is -0.096, -0.116, and -0.034, respectively. In contrast, the correlation between direct restrictions and 2019 catch receipts in all agricultural commodities is 0.215. Results available upon request.

[12]For example, California, Texas and New York have the largest gross state products, and these are generally in the group of states with the most restrictive regulatory language, regardless of industry. Furthermore, the correlation between gross state product and the number of total restrictions in the animal production, animal processing, wholesale distribution, and retail sales industries is 0.334, 0.470, 0.719 and 0.700, respectively.

aquaculture should be interpreted with caution, as regulatory costs may not be restricting growth in industry as much as the estimates appear to suggest.

It should also be noted that regulations are often intended to solve problems and can be good for producers and economic activity. Legal restrictions can be valuable because they protect consumers, protect the environment, define property rights, track economic activity, etc. States and the federal government can thus use restrictions to promote as much as to restrain business, and more restrictions need not imply that a sector or industry is overregulated.

6. Conclusion

Food regulations protect the consumer, mitigate environmental concerns, and promote animal welfare, but they can also hinder innovation, limit entrepreneurship, and generate higher consumer prices (Carter et al., 2021; Malone and Lusk, 2016a, 2016b; McCluskey, Wesseler, and Winfree, 2018; Mullally and Lusk, 2018). Despite an extensive literature on the unintended consequences of regulations, few studies have investigated regulatory restrictions across supply chains. We use Mercatus Center's RegData and State RegData databases to explore regulatory restrictions across various protein supply chains, including beef, pig, poultry, sheep, goat, and seafood. Results suggest that, between 1970 and 2019, the total number of regulatory restrictions at the federal level increased significantly for each protein source, with aquaculture appearing to be the most heavily affected. Further, our results highlight the extreme heterogeneity in the way states regulate animal protein supply chains.

Food policy and food system resiliency have received heightened attention due to the COVID-19 pandemic (Rivera-Ferre et al., 2021; Thilmany et al., 2021; Weersink et al., 2021), concerns over climate change (Hunter and Röös, 2016; Jalil, Tasoff, and Bustamante, 2020), enhanced food insecurity (Gundersen, Kreider, and Pepper, 2017), and consumer sentiment for animal welfare (Clark et al., 2017). Our results demonstrate a patchwork approach to food regulation, which risks creating overlapping, cumbersome guidelines for food manufacturers and industry groups. Additionally, given the interconnectivity of modern food supply chains, the patchwork system can create additional hurdles for interstate commerce, particularly given the significant heterogeneity in food regulations across state boundaries. At a minimum, the cost of a regulation is a compliance cost—the cost of time to read, understand, and abide by the regulation, which can prevent market entry and hinder industry innovation—particularly in emerging, niche markets.

We identify two limitations to our methodology. First, given the lack of granularity of the data, we were unable to partition the state regulatory restrictions by animal protein source. While federal regulatory restrictions use the four-digit NAICS codes (e.g., NAICS 1121: Cattle ranching and farming), State RegData codifies on the three-digit NAICS level (NAICS 112: Animal production). While this limitation prevents a more thorough analysis of the regulatory restrictions at the state level, our analysis provides initial insights into the animal production regulatory patterns across the United States.

Secondly, RegData accounts only for the total number of regulatory restrictions as a proxy for regulatory burden and does not consider any qualitative components of the restrictions. In other words, our approach cannot measure the restrictiveness of each regulatory statement. We acknowledge that there is validity to this concern. Of course, incorporating a method to quality-weight regulatory statements based upon their restrictiveness would offer tremendous insight and enable us to better understand regulatory restrictions. However, no such quality-weighting method exists. Further, RegData offers a substantial improvement over the next-best alternatives (Al-Ubaydli and McLaughlin, 2017), which includes simply counting the total number of pages published in the *Federal Register* or using the size of digitized versions of statutes to measure regulations (Coffey, McLaughlin, and Tollison, 2012; Dawson and Seater, 2013; Mulligan and Shleifer, 2005).

Despite these shortcomings, this article speaks to the changes in regulatory restrictions across protein supply chains over time as well as the heterogeneity among states. While unable to speak to the intensity or cost of each regulatory restriction, we capture the fact that protein supply chains have become subject to tens of thousands of regulatory restrictions. Future research is needed to examine the economic consequences of these regulatory restrictions. By examining changes in industry production practices, market prices, and consumer preferences after significant policy changes, future work could better answer the question of regulatory impacts.

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Appendix

Table A1. I–O supply chain industry weights

		Input weights (α)							
NAICS	Industry description	Cattle ranching and farming (1121)	Poultry and egg production (1123)	Aquaculture and other animals (112X)	Animal processing except poultry (31161A)	Poultry processing (311615)	Seafood processing (3117)	Grocery wholesalers (4244)	Food and beverage retailers (445)
111	Crop production	0.1401	0.0591	0.0273	0.0000	0.0000	0.0000	0.0001	0.0191
112	Animal production	0.4861	0.1277	0.4358	0.7035	0.6296	0.1101	0.0109	0.0018
114	Fishing, hunting and trapping	0.0000	0.0000	0.0000	0.0032	0.0073	0.5886	0.0000	0.0102
115	Support activities for agriculture and forestry	0.0245	0.0161	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000
211	Oil and gas extraction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
212	Mining (except oil and gas)	0.0012	0.0244	0.0037	0.0012	0.0015	0.0058	0.0001	0.0000
221	Utilities	0.0073	0.0101	0.0111	0.0067	0.0134	0.0134	0.0395	0.1126
236	Nonresidential maintenance and repair	0.0000	0.0018	0.0087	0.0010	0.0012	0.0020	0.0032	0.0071
311	Food manufacturing	0.1525	0.6639	0.2885	0.2353	0.2104	0.0965	0.0015	0.0453
312	Breweries	0.0000	0.0061	0.0035	0.0000	0.0000	0.0000	0.0000	0.0022
314	Other textile product mills	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0027
315	Apparel manufacturing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
316	Leather and allied product manufacturing	0.0001	0.0000	0.0025	0.0000	0.0005	0.0000	0.0018	0.0001
321	Wood product manufacturing	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0057	0.0068
322	Paper manufacturing	0.0000	0.0004	0.0000	0.0093	0.0291	0.0215	0.0148	0.0184
323	Printing	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0148	0.0034
324	Petroleum and coal products manufacturing	0.0389	0.0248	0.0311	0.0011	0.0016	0.0075	0.0186	0.0112
325	Chemical manufacturing	0.0180	0.0163	0.0209	0.0003	0.0023	0.0010	0.0050	0.0009
326	Plastics and rubber product manufacturing	0.0029	0.0002	0.0030	0.0060	0.0227	0.0073	0.0450	0.0274
327	Nonmetallic mineral product manufacturing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0011
331	Primary metal manufacturing	0.0004	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

(*Continued*)

Table A1. (*Continued*)

		Input weights (α)							
NAICS	Industry description	Cattle ranching and farming (1121)	Poultry and egg production (1123)	Aquaculture and other animals (112X)	Animal processing except poultry (31161A)	Poultry processing (311615)	Seafood processing (3117)	Grocery wholesalers (4244)	Food and beverage retailers (445)
332	Fabricated metal product manufacturing	0.0206	0.0010	0.0020	0.0006	0.0035	0.0047	0.0044	0.0028
333	Machinery manufacturing	0.0074	0.0018	0.0208	0.0001	0.0002	0.0006	0.0041	0.0017
334	Computer and electronic product manufacturing	0.0000	0.0000	0.0000	0.0002	0.0007	0.0007	0.0004	0.0042
335	Electrical equipment, appliance, and component manufacturing	0.0000	0.0004	0.0049	0.0003	0.0015	0.0000	0.0011	0.0006
336	Transportation equipment manufacturing	0.0012	0.0003	0.0035	0.0003	0.0055	0.0002	0.0227	0.0193
337	Furniture and related product manufacturing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0044	0.0000
339	All other miscellaneous manufacturing	0.0038	0.0001	0.0000	0.0000	0.0000	0.0000	0.0049	0.0018
423	Merchant wholesalers, durable goods	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0090	0.0010
424	Other nondurable goods merchant wholesalers	0.0000	0.0004	0.0000	0.0004	0.0007	0.0121	0.0146	0.0016
425	Wholesale electronic markets and agents and brokers	0.0039	0.0001	0.0094	0.0001	0.0003	0.0008	0.0093	0.0013
481	Air transportation	0.0000	0.0000	0.0000	0.0008	0.0011	0.0013	0.0033	0.0005
482	Rail transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
483	Water transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
484	Truck transportation	0.0000	0.0012	0.0011	0.0000	0.0000	0.0000	0.0040	0.0148
485	Transit and ground passenger transportation	0.0000	0.0000	0.0000	0.0002	0.0003	0.0003	0.0012	0.0001
487	Scenic and sightseeing transportation and support activities for transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0047	0.0231	0.0032
492	Couriers and messengers	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0451	0.0061
493	Warehousing and storage	0.0003	0.0006	0.0018	0.0001	0.0003	0.0006	0.0434	0.1245

(*Continued*)

Table A1. (*Continued*)

		Input weights (α)							
NAICS	Industry description	Cattle ranching and farming (1121)	Poultry and egg production (1123)	Aquaculture and other animals (112X)	Animal processing except poultry (31161A)	Poultry processing (311615)	Seafood processing (3117)	Grocery wholesalers (4244)	Food and beverage retailers (445)
511	Publishing industries (except internet)	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0010	0.0028
512	Motion picture and sound recording industries	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025
517	Telecommunications	0.0017	0.0020	0.0025	0.0007	0.0012	0.0022	0.0165	0.0090
518	Data processing, hosting, and related services	0.0000	0.0000	0.0000	0.0006	0.0013	0.0016	0.0041	0.0098
519	Other information services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034
521	Monetary authorities and depository credit intermediation	0.0038	0.0007	0.0036	0.0011	0.0029	0.0058	0.0211	0.0141
522	Nondepository credit intermediation and related activities	0.0001	0.0004	0.0018	0.0006	0.0010	0.0024	0.0221	0.0297
523	Securities, commodity contracts, and other financial investments	0.0031	0.0002	0.0004	0.0002	0.0005	0.0007	0.0029	0.0032
524	Insurance carriers and related activities	0.0015	0.0044	0.0113	0.0002	0.0006	0.0027	0.0168	0.0122
531	Other real estate	0.0649	0.0102	0.0376	0.0008	0.0005	0.0033	0.0615	0.1711
532	Rental and leasing services	0.0069	0.0044	0.0062	0.0006	0.0011	0.0016	0.0441	0.0065
533	Lessors of nonfinancial intangible assets	0.0000	0.0000	0.0000	0.0009	0.0019	0.0035	0.0165	0.0129
541	Professional, scientific, and technical services	0.0038	0.0154	0.0130	0.0060	0.0084	0.0317	0.1218	0.1058
550	Management of companies and enterprises	0.0000	0.0000	0.0000	0.0112	0.0364	0.0524	0.1663	0.0465
561	Administrative and support services	0.0016	0.0016	0.0021	0.0020	0.0028	0.0043	0.0752	0.0408
562	Waste management and remediation services	0.0008	0.0009	0.0007	0.0010	0.0031	0.0018	0.0033	0.0066
611	Educational services	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0009	0.0147
711	Performing arts, spectator sports, and related industries	0.0000	0.0001	0.0003	0.0001	0.0002	0.0002	0.0024	0.0063

(*Continued*)

Table A1. (*Continued*)

NAICS	Industry description	Cattle ranching and farming (1121)	Poultry and egg production (1123)	Aquaculture and other animals (112X)	Animal processing except poultry (31161A)	Poultry processing (311615)	Seafood processing (3117)	Grocery wholesalers (4244)	Food and beverage retailers (445)
					Input weights (α)				
713	Other amusement and recreation industries	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000	0.0010	0.0006
721	Accommodation	0.0000	0.0000	0.0000	0.0005	0.0007	0.0008	0.0018	0.0009
722	Food service and drinking places	0.0017	0.0016	0.0017	0.0007	0.0012	0.0015	0.0084	0.0115
811	Repair and mainte-nance	0.0000	0.0002	0.0016	0.0018	0.0022	0.0035	0.0456	0.0334
812	Personal and laun-dry services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0009
813	Civic, social, pro-fessional, and similar organiza-tions	0.0001	0.0003	0.0004	0.0001	0.0002	0.0003	0.0026	0.0007

Note: The "X" in the header "Aquaculture & Other Animals (112X)" refers to the final digit of the four-digit NAICS code for: Hog and pig farming (1122); Sheep and goat farming (1124); Aquaculture (1125); and Other animal production (1126). Each of these sectors are assumed to follow the same input weighting.

Note: The "A" in the header "Animal Processing Except Poultry (31161A)" refers to the final digit of the six-digit NAICS code for: Animal (except poultry) slaughtering (311611) ; Meat processed from carcasses (311612); and Rendering and meat byproduct processing (311613). Each of these sectors are assumed to follow the same input weighting.

Table A2. Number of direct restrictions across animal protein value chains

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Processing	Wholesale	Retail sales
NAICS	1121	1122	1123	1124	1125	1129	311X	4244	4451
1970	558	1,194	790	1,072	6,852	1,482	6,999	555	3,034
1971	600	1,221	822	1,109	6,906	1,463	7,438	650	3,040
1972	632	1,340	865	1,154	7,222	1,480	7,845	645	3,578
1973	817	1,598	1,074	1,451	7,823	1,698	8,091	634	3,961
1974	860	1,735	1,295	1,561	8,025	1,736	8,733	631	4,063
1975	906	1,829	1,514	1,631	8,190	1,777	8,772	582	4,115
1976	958	1,873	1,675	1,659	7,763	1,799	9,871	608	3,876
1977	1,011	1,940	1,931	1,774	8,205	1,767	9,561	958	4,009
1978	1,135	2,064	2,358	1,965	8,451	2,011	8,490	1,073	3,446
1979	1,432	2,584	2,885	2,245	8,276	2,211	8,721	1,130	3,904
1980	1,179	2,433	2,820	2,252	9,985	2,090	8,726	1,329	4,538
1981	1,182	2,366	2,757	2,174	11,655	2,079	9,464	1,411	4,823
1982	1,269	2,388	2,629	2,219	12,348	2,065	9,256	1,375	4,561
1983	1,474	2,668	2,960	2,380	13,186	2,268	9,452	1,286	4,429
1984	1,352	2,594	3,177	2,428	13,793	2,368	9,477	1,988	4,561
1985	1,369	2,573	3,274	2,293	14,281	2,393	9,919	1,886	4,677
1986	1,444	2,669	3,278	2,390	15,677	2,454	10,113	1,932	4,904
1987	1,804	2,760	4,177	2,542	15,584	2,543	10,407	2,112	4,940
1988	1,853	2,964	4,352	2,812	15,831	3,002	10,505	2,213	5,063
1989	1,793	3,029	4,691	2,882	17,240	2,915	11,095	2,235	5,521
1990	1,849	3,028	4,732	2,819	17,769	2,986	11,889	2,359	6,418
1991	1,538	2,818	4,657	2,483	18,521	2,898	11,689	2,154	6,034
1992	1,618	2,852	4,585	2,626	20,100	3,063	11,913	2,123	6,956
1993	1,870	3,438	4,789	3,270	21,905	3,166	12,461	2,062	8,071
1994	2,229	3,797	5,264	3,725	23,487	3,760	12,886	2,161	8,885
1995	2,193	3,603	4,901	3,623	22,815	3,354	12,668	1,887	9,227
1996	2,196	3,632	4,780	3,706	22,106	3,227	13,587	2,948	9,062
1997	2,353	4,136	4,145	3,895	23,688	3,577	13,526	2,671	7,395
1998	2,437	4,229	4,213	4,010	24,210	3,578	13,606	2,764	7,339
1999	2,653	4,345	4,646	4,145	24,902	3,567	13,703	2,648	7,220
2000	2,908	4,528	4,836	4,350	26,171	3,752	14,317	2,650	7,226
2001	3,092	4,740	5,204	4,682	27,128	4,166	14,791	2,823	8,556
2002	3,095	4,779	5,229	4,730	27,255	4,183	15,111	2,912	7,846
2003	3,443	5,014	5,456	4,946	28,347	4,203	15,052	3,178	7,833
2004	3,540	5,065	5,415	4,969	26,044	4,185	14,972	3,681	7,641

(*Continued*)

Table A2. (*Continued*)

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Processing	Wholesale	Retail sales
2005	3,616	5,175	5,608	5,125	27,653	4,407	14,885	3,760	7,780
2006	3,533	4,971	5,385	4,988	29,308	4,177	14,655	3,908	7,841
2007	3,556	5,006	5,424	5,023	29,569	4,288	14,680	4,158	8,079
2008	3,480	4,989	5,453	5,036	30,040	4,358	17,630	4,371	7,999
2009	3,699	5,222	5,608	5,226	32,435	4,458	17,490	4,612	7,896
2010	3,567	5,248	5,536	5,252	33,054	4,323	17,599	5,084	8,005
2011	3,589	5,294	5,415	5,387	33,916	4,384	17,819	5,217	9,764
2012	3,720	5,525	5,687	5,636	35,595	4,595	19,147	5,147	9,819
2013	3,627	5,492	5,641	5,616	35,494	4,597	19,506	5,390	9,952
2014	3,374	5,532	5,465	5,666	36,585	4,603	18,961	5,692	10,022
2015	3,487	5,684	5,751	5,767	36,976	4,579	19,853	5,446	10,510
2016	3,696	6,201	6,149	6,309	37,722	4,790	22,899	5,859	10,143
2017	3,722	6,404	6,264	6,423	47,221	5,210	23,174	5,242	11,784
2018	3,737	6,447	6,359	6,469	47,760	5,246	23,177	5,178	11,898
2019	3,761	6,505	6,256	6,511	48,843	5,323	22,903	5,027	11,839

Processing modeled using NAICS sectors 311611 to 311613, 311615, and 3117.

Table A3. Total number of direct and indirect restrictions across animal protein value chains

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Processing	Wholesale	Retail sales
NAICS	1121	1122	1123	1124	1125	1129	311X	4244	4451
1970	7,726	8,905	9,651	8,783	14,563	9,194	27,844	5,730	8,133
1971	7,969	8,843	9,245	8,731	14,528	9,086	28,273	6,456	8,732
1972	7,717	8,776	9,573	8,590	14,658	8,915	28,242	7,685	10,363
1973	8,265	9,255	9,715	9,108	15,481	9,356	29,205	7,993	11,031
1974	8,877	9,900	10,176	9,725	16,190	9,901	31,652	8,534	11,653
1975	9,628	11,069	12,304	10,871	17,430	11,017	34,078	9,419	12,633
1976	9,839	11,299	12,577	11,084	17,189	11,224	35,789	9,920	12,801
1977	10,016	11,357	12,044	11,191	17,622	11,183	36,114	11,086	13,508
1978	11,083	12,074	12,482	11,975	18,461	12,020	37,091	11,387	13,114
1979	11,433	12,733	13,717	12,395	18,425	12,361	37,232	11,893	13,991
1980	11,820	13,153	13,609	12,972	20,706	12,810	39,262	12,780	15,341
1981	11,964	13,486	13,758	13,293	22,774	13,199	41,429	14,268	16,926
1982	12,760	14,174	14,114	14,005	24,134	13,851	43,324	14,375	16,835
1983	12,986	14,431	14,407	14,143	24,950	14,032	43,364	13,741	16,243
1984	13,155	14,757	14,982	14,590	25,956	14,531	44,249	16,295	17,824
1985	13,000	14,430	15,278	14,151	26,138	14,250	43,914	14,780	16,957
1986	13,787	15,220	15,521	14,941	28,228	15,004	46,132	15,099	17,471
1987	15,048	16,195	17,126	15,977	29,019	15,978	48,981	15,898	18,067
1988	15,219	16,487	17,371	16,335	29,354	16,526	49,113	16,845	18,949
1989	15,715	16,987	17,830	16,840	31,198	16,873	51,131	18,189	20,483
1990	16,230	17,376	18,098	17,168	32,118	17,334	53,027	19,040	21,934
1991	16,153	17,475	18,268	17,140	33,179	17,556	53,713	18,946	21,703
1992	17,262	18,473	18,664	18,247	35,721	18,683	56,979	19,134	22,774
1993	18,233	19,558	18,943	19,391	38,025	19,286	58,755	18,999	23,626
1994	20,280	21,948	21,724	21,876	41,638	21,912	63,931	20,380	25,752
1995	20,685	22,227	21,715	22,247	41,439	21,978	64,854	20,278	26,231
1996	19,751	21,345	20,874	21,419	39,819	20,941	62,612	20,302	25,416
1997	20,231	22,051	20,084	21,810	41,604	21,492	63,017	21,916	25,330
1998	20,915	22,628	20,324	22,408	42,608	21,976	64,907	21,804	25,162
1999	21,889	23,380	21,094	23,180	43,936	22,602	66,167	21,659	25,037
2000	22,055	22,753	18,404	22,575	44,397	21,977	65,499	21,914	25,047
2001	23,365	23,784	18,935	23,726	46,172	23,210	68,282	22,533	26,758
2002	23,880	24,323	19,369	24,274	46,799	23,727	69,462	23,168	26,489
2003	24,407	24,779	19,741	24,712	48,112	23,968	69,374	23,581	26,581
2004	22,369	22,888	18,968	22,792	43,867	22,007	63,655	23,827	26,131

(*Continued*)

Table A3. (*Continued*)

	Cattle ranching	Hog and pig	Poultry and egg	Sheep and goat	Aquaculture	Other animal	Processing	Wholesale	Retail sales
2005	22,811	23,338	19,265	23,288	45,816	22,570	64,838	24,154	26,525
2006	23,682	24,048	19,402	24,065	48,385	23,254	66,832	24,582	26,871
2007	23,538	24,010	19,565	24,027	48,573	23,292	66,778	25,277	27,606
2008	24,066	24,557	20,125	24,605	49,609	23,927	71,110	25,920	27,902
2009	25,108	25,553	20,645	25,557	52,766	24,789	73,321	26,560	28,149
2010	25,412	25,985	20,724	25,989	53,791	25,059	74,968	27,215	28,419
2011	26,142	26,761	21,132	26,854	55,383	25,850	76,792	28,523	31,507
2012	27,530	28,286	22,446	28,397	58,356	27,356	81,845	29,097	32,477
2013	28,119	28,931	22,792	29,055	58,934	28,037	83,737	30,036	34,160
2014	28,134	29,184	22,798	29,318	60,237	28,255	83,626	31,125	35,523
2015	28,848	29,889	23,382	29,972	61,180	28,784	86,180	30,475	35,490
2016	29,076	30,529	24,331	30,637	62,050	29,118	88,023	31,513	35,780
2017	36,474	37,269	26,937	37,288	78,086	36,075	108,167	32,120	38,899
2018	36,519	37,328	27,050	37,349	78,640	36,127	108,033	31,941	38,960
2019	36,515	37,435	26,526	37,441	79,773	36,253	108,045	31,732	38,742

Processing modeled using NAICS sectors 311611 to 311613, 311615, and 3117.