



Agricultural and Resource Economics ARE UPDATE

Giannini Foundation of Agricultural Economics, University of California

Vol. 21, No. 1 Sep/Oct 2017

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The True Value of California Wine Grapes

Olena Sambucci and Julian M. Alston

The method used to calculate average statewide returns per ton of wine grapes in the California Grape Crush Report understates the true total value of the crush significantly. We suggest an alternative method that will provide more accurate estimates.

The Crush Report is an authoritative source of information on the average returns per ton received by growers of wine grapes in California. In fact, it is the only source of detailed information about average returns per ton and tons crushed at the level of crush district and by variety. The USDA National Agricultural Statistics Service (NASS) uses data provided in the Crush Report to calculate the total value of wine grape production, as reported in the annual Agricultural Statistical reports and California Statistics reports (available online). Data from the Crush Report are also used by major industry publications (e.g., Wine Institute, 2015), as well as in economic studies of the California grape industry.

In a recent article in the *Journal of Wine Economics* (Sambucci and Alston, 2017), we showed that these estimates may have understated the true total value of the crush by 14–20% in recent years. The source of the error in calculating the average return per ton, and thus the total value of the grape crush, is variation among regions in the structure of the wine grape industry in terms of the average price per ton and the share of production used in-house (grapes crushed to growers' accounts and used for in-house winemaking) versus sold to others.

The prices of wine grapes are observed directly only for those wine grapes that are sold; not for those crushed to growers' accounts. The shares of wine grapes crushed to growers' accounts vary systematically among regions: a greater proportion of the total crush is crushed to growers' accounts (and thus not sold) in districts with higher-valued wine grapes. Consequently, the average value per ton of all wine grapes is greater than the average value per ton of wine grapes that are sold.

The Crush Report applies the average value per ton of wine grapes that are sold to total volume, which results in an underestimate of total value. In this article we show how a more accurate estimate can be calculated by using

the prices of wine grapes that are sold to infer the prices of wine grapes that are not sold before computing the weighted average return per ton. According to our estimates using this revised procedure, the value of wine grapes produced in California in 2016 was \$3.6 billion, 15.8% greater than the official measure.

Calculation of Prices in the Crush Report

The Crush Report contains information on the total quantity of wine grapes crushed (in tons), which includes both grapes that are sold and grapes that are not sold. Specifically, the 2016 Final Crush Report includes details by type, variety, and reporting district of total tons of grapes crushed (Crush Report Table 2), tons of grapes purchased (Crush Report Table 4), and tons of grapes crushed to growers' accounts (Crush Report Table 9)—all provided for each of 17 individual crush reporting districts and for the state as a whole.

Prices per ton of grapes are observed only for quantities of grapes that are sold. The details of the prices paid to growers for purchased tonnage by type, variety, and reporting district are included in Crush Report Table 8. As these data reveal, even within a season, prices for the same variety



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in the same crush district can vary considerably. For example, in crush district 4 (Napa) the price of Cabernet Sauvignon ranged from a low of less than \$1,000/ton, for a total of 70.2 tons in four lots, up to a high of more than \$40,000/ton for a total of 25.8 tons in two lots. Comparable measures of unit value are not observed for grapes crushed to growers' accounts (i.e., not sold), and must be inferred.

Whilst we do not observe value per ton of grapes that are crushed to growers' accounts, we do observe the proportion of the crush that is sold for each variety and crush district. The general pattern is that the districts with higher-priced grapes (e.g., crush districts 3 and 4 in the North Coast region) also have greater shares of grapes crushed to growers' accounts. Consequently, the statewide average

value of grapes crushed to growers' accounts will be greater than the average price per ton for grapes sold to others, and hence the true average return per ton will be larger than the return per ton given in the Crush Report. Estimates of the total value of the crush using this downward-biased estimate of the average value per ton will be biased down accordingly.

Numerical Illustration

In the analysis that follows, we have organized the data by production regions, defined such that each crush district fits entirely into one region. Production regions differ in terms of their terrain, climate, soil types, mixture of varieties grown, and quality of grapes and wines produced.

We compute and compare average prices both as they are done in the Crush Report and using an alternative approach in which the prices of wine grapes that are sold are used to infer the prices of wine grapes that are crushed to growers' accounts before computing the weighted average return per ton. Table 1 includes estimates of regional and statewide average prices for wine grapes in 2016 calculated using observed district-specific average prices for wine grapes that were sold applied to both: (a) just the quantities sold (in column 3) as in the Crush Report; and (b) the total quantities crushed (in column 4), our suggested alternative measure. The implied regional and statewide total value of wine grapes crushed are also reported in Table 1, in columns (5) and (6).

Within regions, the differences in the estimated prices between columns (3) and (4) are generally modest. However, when we aggregate to the state as a whole, the bias becomes greater. The statewide average value of wine grapes calculated using average returns per ton from the Crush Report is \$780/ton, while the value per ton

Table 1. Alternative Estimates of Average Wine Grape Values, 2016 Data

(1) Region	(2) Crush District	(3) Average Return		(5) Value	
		(3) Purchased Tons Only	(4) All Crushed Tons	(5) Using Crush Report Prices (column 3)	(6) Using Alternative Measure of Prices (column 4)
		\$ per Ton		\$ Million	
Napa-Sonoma	3, 4	3,390	3,486	1,286.4	1,322.9
Central Coast	7, 8	1,516	1,515	747.6	747.4
S. Central Valley	13, 14	305	306	472.1	473.3
N. Central Valley	9, 11, 12, 17	573	564	806.4	793.5
Other California	All others	1,424	1,483	289.2	301.2
California		780	903	3,142.6	3,638.3

Notes: Prices were calculated using values for total tons and tons sold from Table 2. Prices for each region were calculated using data from the Grape Crush Report, district-level detail by variety.

calculated using our alternative measure is \$903/ton. Applying these average unit values to the total volume of wine grapes produced, the implied estimates of the total value of production in 2016 differ by about \$0.5 billion in 2016, 13.6% of the larger estimate (15.8% of the smaller estimate).

The Role of Regional Diversity

Table 2 provides information on the regional differences in production patterns that account for these discrepancies. In general, the share of production crushed to growers' accounts is greater for Napa-Sonoma and the Central Coast, where average prices per ton are generally higher, and smaller for the Northern and Southern Central Valley regions, where average prices per ton are much lower, but the volume of production is large.

Columns (2) and (3) in Table 2 include two measures of production for each region: total tons crushed and tons sold. The ratio of total tons sold to total tons crushed in column (4) is the region-specific measure of the share of production that is sold rather than crushed to growers' accounts. Among regions, these shares differ appreciably, from 95% in the Southern Central Valley to 62% in Napa-Sonoma. The regions also differ in terms of their relative importance as producers. The last two columns show the region-specific shares of total tons crushed and of the total quantity that is sold rather than crushed to growers' accounts. Among regions, these shares differ appreciably, too—the Central Valley regions account for over 73% of the total volume and 79% of the volume sold.

The regional average prices per ton do not differ too much between the two methods of calculation: as shown in detail in Table 1, the difference is at most 7%, and it is between 0 and 3% for regions where most of the volume is produced. However, when

Table 2. Characteristics of Grape Growing Regions in California

(1)	(2)	(3)	(4)	(5)	(6)
Region	Tons Crushed (Thousands)		Tons Sold as a Share of Tons Crushed	District Quantity as a Share of State Total	
	Total	Sold		Total Tons	Tons Sold
Napa-Sonoma	379.5	234.2	0.62	0.09	0.07
Central Coast	493.3	330.4	0.67	0.12	0.10
S. Central Valley	1,549.0	1,478.5	0.95	0.38	0.44
N. Central Valley	1,406.4	1,187.7	0.84	0.35	0.35
Other California	203.1	143.1	0.70	0.05	0.04
California	4,031.1	3,374.0	0.84	1.00	1.00

Sources: Alston, Andersen, and Sambucci (2015), own calculations using data from CDFA.

the average weighted return is calculated for the state, the difference between the two methods of calculation becomes quite large. Weighting the average return per ton by tons sold under-represents the value of production in the coastal valleys where larger shares of production are crushed to growers' accounts—in particular in the Napa-Sonoma and Central Coast regions. Conversely, disproportionate weight is given to prices from areas where growers sell nearly all their production of wine grapes, in particular the Southern and Northern Central Valley regions that produce a very large volume of lower-priced grapes.

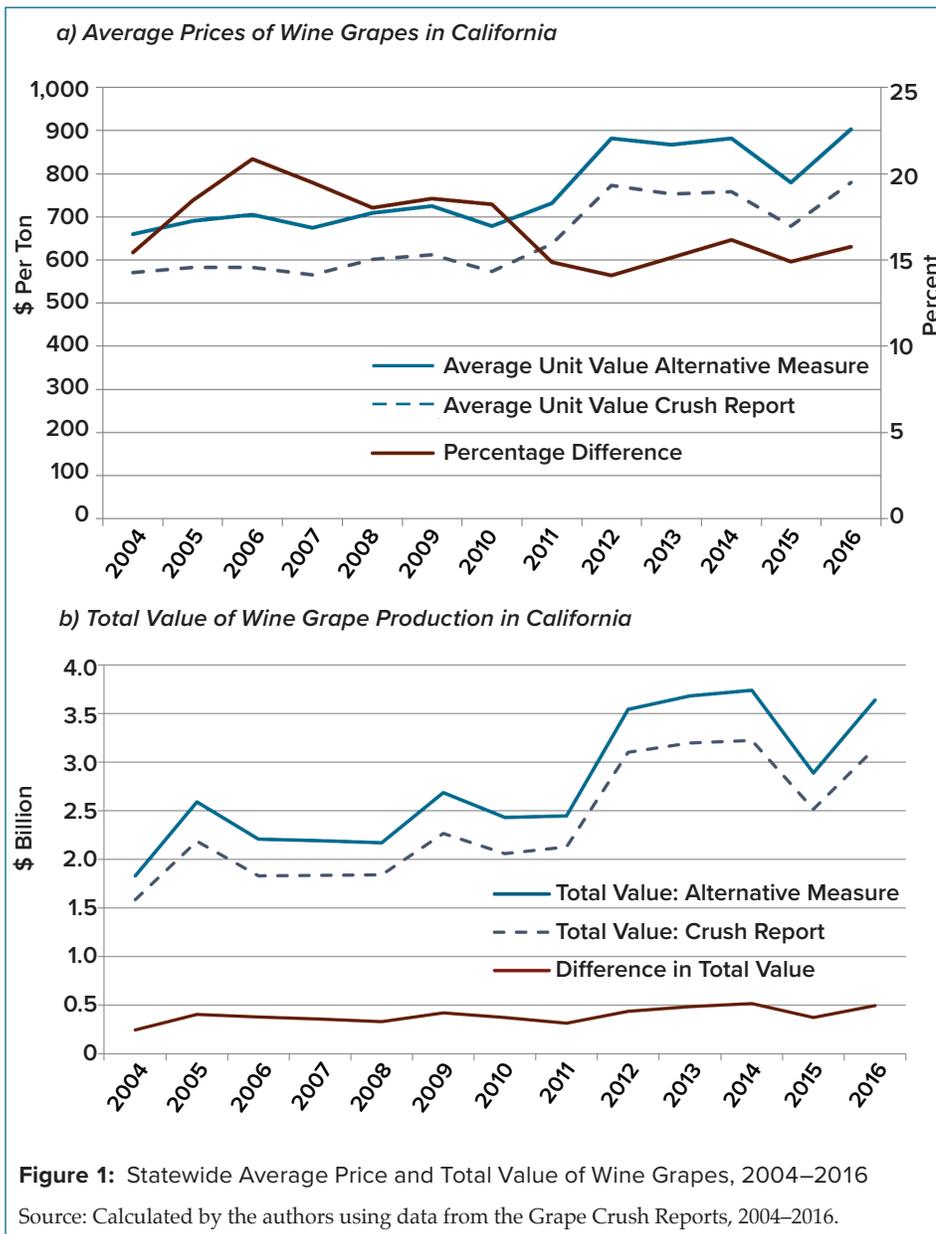
The estimated average value per ton of wine grapes crushed for each district is calculated using the same method and therefore is susceptible to the same type of error. However, for each variety, its share of the total tons crushed within a district is usually similar to its share of the purchased tons within the same district (i.e., the share of production crushed to growers' accounts is similar across varieties within a district). And, in Table 1, columns (3) and (4), we see small differences between the two estimates of average prices even when aggregated

to the regional level. Therefore, the difference between the two methods of calculating state-level prices is mainly attributable to the difference among districts in their shares of total state production compared with their shares of state production that is sold, given the general patterns of prices among districts.

Year-to-Year Variation

The composition of the crush varies from year to year, and, consequently, so does the discrepancy between the alternative methods of estimating the district, regional, and statewide average prices. Figure 1 shows the difference between the estimated average statewide return per ton calculated using the two methods described above for each year during the period 2004–2016.

The average difference in price is about 17% of the lower value, with 2006 having the largest difference of just over 20%. The average difference in price of 17% over the past 10 years implies estimates of value that understate the value of wine grape production by about \$400 million per year compared with our preferred method. Errors of this magnitude may have led



to USDA/NASS incorrectly reporting grapes as the second-largest agricultural crop by value in California, after almonds when, in fact, grapes were the largest crop by value in 2011, 2013, and 2015.

Conclusion

The general lesson here is that, even when using information from well-established and familiar sources, it is important to make an effort to understand how the data were created. Given what we know about the structure of the wine grape industry, we propose an alternative to the method used to compute average crush prices

and the total value of the California wine grape crush in the Crush Report. The difference between the two methods of calculating average weighted returns per ton of California wine grapes at crush stems directly from differences among crush districts in the shares of production crushed to growers' accounts, in conjunction with the patterns of prices and production among crush districts. The discrepancy varies among years but is appreciable in every year for which we have done the calculations, 2004–2016. California's wine grape production is even more valuable than you might have thought!

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Suggested Citation:

Sambucci, Olena, and Julian M. Alston. "The True Value of California Wine Grapes." *ARE Update* 21(1) (2017): 1–4. University of California Giannini Foundation of Agricultural Economics.

For additional information, the authors recommend:

California Department of Food and Agriculture (CDFA). Current and historical Grape Crush Reports available at: https://www.nass.usda.gov/Statistics_by_State/California/Publications/Grape_Crush/Reports/

Sambucci and Alston (2017). Estimating the Value of California Wine Grapes. *Journal of Wine Economics*. DOI: <https://doi.org/10.1017/jwe.2017.9>. Published online June 8, 2017.

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Establishing Supply Chain for an Innovation: The Case of Prepackaged Salad

James Lugg, Myung Eun Shim, and David Zilberman

The agrifood sector is subject to continuous innovations introduced by researchers or practitioners. Implementation of innovation requires a well-designed product supply chain that enables relentless innovation and meets consumer needs. Prepackaged salads are an important California-based innovation that utilize new technologies to design supply chains for new and improved products.

Food choices available to consumers have dramatically increased over the past 50 years, reflecting product and process innovations. Consumers can purchase exotic fruits and vegetables year-round, prepackaged salads and ready-to-eat meals, but innovations are ideas and concepts, so innovators face two challenges. The first challenge is to translate innovations into working processes and products—accomplished through the innovation supply chain. The second is to utilize these processes and bring products to market—done through the product supply chain. This article describes how both systems work, in general, and then illustrates them.

We illustrate the innovation supply chain through the case of controlled-atmosphere storage, and the product supply chain through prepackaged salads. We show that the wide array of ready-to-eat salads we

enjoy today originated in experimental research that started in the early 19th century, both in the private and public sectors. Entrepreneurs applied these tools through further research and commercialization efforts that pursued value-added consumer products to meet the demand for convenience, taste, and freshness.

The Innovation Supply Chain

Practitioners or scientists at universities or in industry may originate innovations. Commercialization of innovations requires establishing working processes, upscaling them, and testing them for efficacy and safety. Research leading to a working output is gradual. Innovators may obtain patents or trade secrets and contribute to a growing body of knowledge through research literature.

Some public sector innovations (e.g., from USDA, research universities) may be made available freely to users. But public sector capacity to develop innovations is limited, and therefore universities establish offices of technology transfer (OTT) to transfer or sell the right to utilize their patents to the private sector. The exclusivity that the patents allow motivates firms to invest in their innovations.

Investment in the development of innovations is risky, and many patents do not find existing firms that want to develop them. In these cases, universities may sell rights to develop technologies to startups, sometimes involving the scientists who invented the product. In other cases, the OTT can sell to a firm the right to develop the technology. Some major companies, like Amgen, were launched based on university patents, and some startups based on University of California technologies were sold to large companies (e.g., Monsanto purchased CalGene).

The innovation process is time-consuming. It may start with

discoveries of principles that are followed up with scientific experiments at different scales, which refine and expand the knowledge base, resulting in methodologies available for commercial applications. This process may be carried out by multiple organizations, both private and public, and benefit from the exchange of knowledge through publications and experience gained with early applications.

The Case of Controlled-Atmosphere Storage

The search for methods to maintain freshness in produce has been going on for millennia. For example, traders buried fruit underground, and ship captains kept them in unventilated holds. However, in 1820, a French chemistry professor, J.E. Berard, realized that fruits utilize oxygen and emit carbon dioxide, and denying oxygen delays the ripening process. Several practitioners applied this knowledge to develop storage facilities, but to use these efficiently, more quantitative applied research was required. Government researchers in Cambridge, England, established parameters for the preservation of different fruits in the 1920s.

Drawing on this research, UC Davis pomologists working with a private company experimented with cold storage facilities in Watsonville, mostly to preserve apples. Cornell and other universities conducted parallel lines of research, in which they established parameters of temperature ranges and oxygen levels to preserve various fruits. A key challenge was to control the atmosphere continuously, and Whirlpool Corporation, using its expertise in refrigeration, developed TECTROL®, a “total environmental control” system in the early 1960s—mostly for the purpose of storing and shipping fruit.

Dana Dalrymple’s 1969 study of this history, “The Development of

Table 1. Packaged Salad Sales, 52 Weeks, 2015/16

Prepackaged Salad Sales		
Prepackaged Salad Varieties	Dollar Sales	Dollar % Change vs. Previous 52 Weeks
Packaged Salad (All)	\$3,700,000,000	8%
Salad Blends	\$964,308,383	-1%
Completes/Kits	\$950,103,180	31%
Organic Salad	\$715,774,511	12%
Premium Garden Salad	\$425,867,408	-4%
Regular Garden Salad	\$404,867,985	2%
Coleslaw	\$116,481,678	2%
Broad Leaf Spinach Salad	\$58,639,562	-1%
Broccoli Slaw	\$33,669,723	3%

Source: Nielson Perishables Group FreshFacts, 52 weeks ending April 2, 2016.

an Agricultural Technology: Controlled-Atmosphere Storage of Fruit," suggests that the development of the technology was "the subject of years of publicly financed study...[o]nly after considerable laboratory work was the technique taken out for preliminary tests...[a]s the trials proved successful, commercial use expanded."

The innovation process leads to viable technologies, and TECTROL® is the technology used currently for controlled atmosphere storage. We will show how this technology has been applied to provide prepackaged salads, and furthermore demonstrate the evolution of the supply chain for this product.

The Product Supply Chain

Once the product and technology to produce it have been developed, the firm that owns it needs to develop the product supply chain. In the case of agrifood products, the supply chain may include many stages, including production of "feedstock," which is an agricultural product, processing the feedstock, shipping, wholesaling, retailing, etc.

The simplest supply chain has two stages, including on-farm production of an agricultural product and off-farm activities of processing and

shipping. The firm that controls the technology is likely to design the supply chain to maximize its average return on investment adjusting for risk. Some constraints on these choices of the firm include credit availability, managerial capacity, access to labor and land, along with other inputs. The firm has to determine the productive capacity, namely the size of processing facilities and feedstock required. Furthermore, the firm must determine how much of the feedstock to produce in-house and how much to buy from others.

One strategy is to have a vertically integrated operation where the firm produces all feedstock and the final product. Another strategy is to concentrate on processing and obtain all or part of the feedstock from the market (i.e., contracting). Vertical integration may limit the size of the operation, but reduce the dependency on suppliers. Contracting feedstock reduces the costs of investment in capital for production of feedstocks.

Each strategy has a different risk profile and firms may take a mixed strategy. Frequently, innovators who introduce new products start at a small scale, controlling both feedstock production and processing, and perfecting both processes. Over time, they

may engage in partnership in production of feedstock, or even processing. It is also possible that some may even sell the right to use the technology to others.

It is important to keep in mind that firms operate in a dynamic environment and the introduction of new agrifood products involves continuous learning and adaptation. Both the production costs and processing costs are likely to decline over time on a per-unit basis due to "learning by doing" at the firm level. Product characteristics may change when the firm is more aware of consumer preferences. Over time, a product may include more varieties to accommodate differentiated tastes among consumers.

When a product is successful, the scale of the operation increases over time, the number of processing facilities increases, and the product distribution network expands geographically. Quite frequently, once a new product is established, the initial innovator encounters competitors developing similar products. Every innovation has its own evolution process, and an effective way to understand the design of innovation and product supply chain is to learn from case studies. The case study of prepackaged salads illustrates some of the basic principles discussed above.

Prepackaged Salads and Fresh Express

Lettuce is one of the major crops produced in California, mostly in the Central Coast region. Bruce Church, Inc. was a family-owned major lettuce producer that produced 7% of the U.S. head lettuce supply in the 1960s. The company was concerned about the instability of the price of lettuce and was ready to venture into innovative activities. It also realized that, because lettuce was perishable, keeping it fresh during the shipping process was a major challenge; therefore, potential

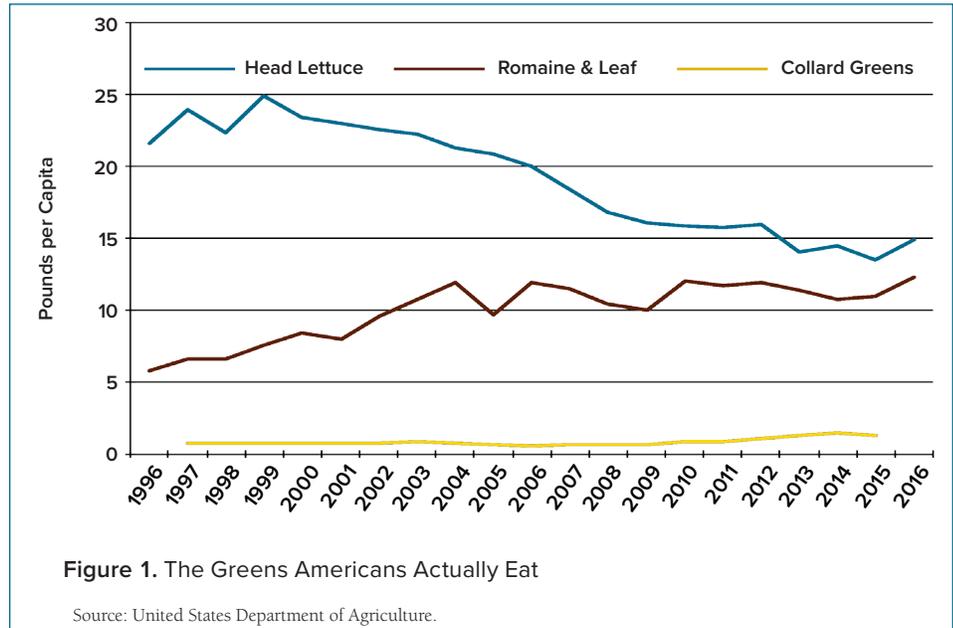
gains existed if shipping and processing were improved.

The innovation was to apply controlled and modified atmosphere solutions, like TECTROL®, to preserve lettuce in storage and shipment. As we mentioned, Whirlpool Corporation owned the rights to TECTROL® so Bruce Church and Whirlpool Corporation established a research unit, TransFRESH Corporation, to develop and implement the technology for shipping lettuce in a controlled or modified environment.

In 1968 experiments using cut lettuce were initiated, and by the mid-1970s, a viable technology emerged. The research found the right formula to manage oxygen and carbon dioxide for mixtures of leafy greens inside the enclosure to preserve freshness. The new technology revolutionized the leafy green market.

Until the 1970s, leafy greens like lettuce went to market as trimmed or whole heads packed in cooled corrugated boxes. The new technology enabled the packaging of lightly processed leafy greens into large plastic bags for shipping to fast food outlets or large institutions. The package contained either all iceberg lettuce or a mixture of iceberg lettuce with shredded red cabbage and carrots. A company called TrimFresh was established to sell the processed leafy greens, obtaining the feedstock from Bruce Church and other farms.

However, as the innovation process continued to develop, the company realized another potentially more promising product line—prepackaged salads. Surveys showed that consumers were aware that they discarded much of the lettuce when they bought whole heads, and that they liked variety in the salad and disliked the preparation effort. The pursuit of convenience, taste, and health generated willingness to pay for prepackaged salads.



By 1989 scientists were able to develop packaged salads to have a 14-day shelf life and introduced salad blends to the market. To introduce these new products, a new company named Fresh Express formed in 1986. In order to finance the expansion of prepackaged salad production, Bruce Church sold its farms and relied on other farms to provide the feedstock, which were different types of lettuce and other vegetables. The transition to prepackaged vegetables also led the industry to move away from free on board (FOB) pricing towards contracting. Over time, the length of the contracts increased and allowed growers to have more certainty.

To expand consumer demand for prepackaged salads, Fresh Express and others increased product diversity by adding in other vegetables, including spinach and carrots. To enhance the value of prepackaged salads, they added meat products, like chicken and bacon, as well as salad dressing. To increase product differentiation, entrepreneurs incorporated exotic products like kale and quinoa, which became prominent components in prepackaged salads. Over time, several competent companies entered the prepackaged salad market after obtaining

the right to freshness technology or by developing their own formulas. Today, supermarkets may devote about 10% of their vegetable shelf space to these packages.

According to Nielson Perishable Group FreshFacts, in 2016 Americans bought twice as many prepackaged salads as whole lettuce heads. Prepackaged sales in the U.S. generated \$3.7 billion in 2015 (see Table 1), and the rate of growth for prepackaged salads was 8%, with organic salads growing at 12%.

The improvement in the transport of leafy greens associated with Trans-Fresh technologies also changed the composition of products consumed. In particular, there was a transition away from iceberg lettuce with a longer shelf life to both leaf and romaine lettuce, which are more attractive in salad kits (see Figure 1).

With prepackaged salads, there was an obvious increase in consumption of collard greens and spinach from the 1980s (spinach consumption slowed after major food safety incidents in 2008). While the consumption of kale is small, it has seen a remarkable 400% increase in appearance on restaurant menus over the past five years.



Growers are transitioning away from iceberg lettuce with a longer shelf life to leaf and romaine lettuce, which are more attractive in salad kits.

Prepackaged salads are now part of the ready-to-eat prepackaged fruits and vegetables sector, with estimated sales of \$5.5 billion in 2014 and projected sales of \$7 billion in 2018. The prepackaged salad revolution is now global, as sales of prepackaged fruits and vegetables in Europe are of the same order of magnitude as the United States. While still small, they are growing significantly in Asia as well.

Conclusions and Implications

The emergence of prepackaged salads resulted from both a continuous innovation supply chain that enabled a technology to be applied to leafy greens, along with a product supply chain to process, store, and distribute a growing range of value-added agri-food consumer products. The entire process, from the basic discovery of the principles of extending storage life for fruits and vegetables to the differentiated prepackaged salad product, has taken close to 200 years, and it continues to advance today.

Introduction of successful new products requires identifying features for which consumers are willing to pay,

which in this case includes convenience, diversity, and healthfulness. The innovators need the capacity to take advantage of new scientific knowledge, obtain talent to develop it further, and obtain capital to invest in research and development activities, productive capacity, and distribution infrastructure. California has been at the forefront of these innovations because of its advanced agriculture, the availability of well-trained scientists, and the close collaboration between the private sector and universities.

The development of new products, like processed food and prepackaged salads, is also associated with the capacity to introduce new crops, as exemplified by kale and quinoa. Thus, development of new and appealing crops, as well as techniques to provide them as part of a large portfolio of products to consumers in a convenient manner, will be part of the challenge for the agrifood sector.

Prepackaged salad exemplifies the strong capacity of the industrial-education complex in California to come up with new innovations and develop

the supply chains to implement them. Controlled atmosphere storage and prepackaged salads emphasize the importance of public-private collaboration in research and development. Additionally, it emphasizes the need to continually develop our scientific knowledge base, upgrade the skills and capacity to convert innovation to new products, and to design effective and profitable innovation and product supply chains. Understanding and applying sound economic principles are critical for the efficient allocation of resources between research and development, feedstock and processing and distribution capacity that leads to successful innovation and product supply chains.

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Suggested Citation:

Lugg, James, Myung Eun Shim, and David Zilberman. "Establishing Supply Chain for an Innovation: The Case of Prepackaged Salad." *ARE Update* 20(6) (2017): 5–8. University of California Giannini Foundation of Agricultural Economics.

Economic Consequences of New Federal and State Regulations to Limit Antibiotic Use in Livestock

Tina L. Saitone

Antibiotic resistance is one of the most pressing public health challenges facing the world today. In response, regulations have been put in place to limit the use of antibiotics in food-producing animals for growth promotion and to increase feed efficiency. These changes are likely to reduce productivity and have market-level impacts on output and prices.

According to the World Health Organization, antibiotic resistance is one of most substantial threats to global health and food security. The Centers for Disease Control and Prevention (CDC) report that two million people in the U.S. each year become infected with bacteria that are resistant to antibiotics, with 23,000 of those individuals dying as a result. Antibiotic resistance compromises the medical and veterinary communities' ability to effectively fight infectious diseases and manage infectious complications, which has serious health implications worldwide, while adding considerable costs to the treatment and control of disease.

Bacteria become resistant to antibiotics by mutating in a way that reduces or eliminates a given drug's effectiveness. Most health organizations cite the misuse or overuse of antibiotics in humans and animals as the primary factor contributing to the spread and increase in antibiotic resistance globally. While concerns about

resistance are paramount in both the human- and animal-health arenas, the food-producing animal segment (e.g., beef cattle, dairy cattle, poultry) of the supply chain has been widely criticized for using antibiotics for growth promotion and enhanced feed efficiency (i.e., subtherapeutic uses). Subtherapeutic antibiotic use in animals may manifest through low-levels of antibiotics administered for an extended period of time. According to the CDC, this type of long-term, low-level exposure contributes to the survival and growth of resistant bacteria.

When resistant bacteria are present in animals, they may be transmitted to humans through water and/or soil not washed off of food, improperly cooked meat, and exposure to animal feces. CDC reports 1 in 5 antibiotic-resistant infections in humans are caused by bacteria from food and animals.

In this article, I examine the new federal regulation and compare it to similar state-level regulations coming into effect in California in January 2018. I look at likely cost impacts for consumers and market-level impacts on prices, output, and competitiveness of California and U.S. producers relative to producers located elsewhere.

Regulatory Changes Governing Antibiotic Use in Food-Producing Animals

In response to these growing concerns, the Department of Health and Human Services' Food and Drug Administration (FDA) has amended the Animal Drug Availability Act of 1996 to add further structure to the distribution and administration of antibiotics to food-producing animals. Prior to this amendment, all animal drugs were regulated as either prescription or over the counter. These federal regulatory changes, which were fully implemented on January 1, 2017, defined a new avenue to

distribute antibiotics used in or on animal feed or administered through water. The regulations also defined antibiotics that are considered "medically important," an antibiotic used in both humans and animals (also referred to as shared class). Further, the FDA asked companies that produce these drugs to change their labels to eliminate any reference to or direction associated with subtherapeutic uses and to change the means of sale to eliminate any over-the-counter option.

Following these changes, it is illegal to use any medically important antibiotic for subtherapeutic treatments. Moreover, this class of drugs can only be used to treat, prevent, or control disease in animals under the supervision of a licensed veterinarian. This supervision is provided through a veterinary feed directive (VFD), which closely resembles a prescription for feed- or water-based antibiotic treatment. Prior to implementation of what has become known as the VFD rule, feed- and water-based medically important antibiotics were available over the counter and used at the discretion of farmers/ranchers without veterinarian oversight.

At roughly the same time as that VFD rule went into effect, California Governor Jerry Brown signed Senate Bill 27 ("Livestock: Use of Antimicrobial Drugs"). This bill, effective beginning January 1, 2018, implements regulations in California that are similar to the federal VFD rule with a few exceptions. Table 1 compares the federal and California regulations.

Beyond increasing the limitations on use of medically important antibiotics, relative to the federal rules, SB 27 also mandates that the California Department of Food and Agriculture (CDFA) develops and distributes stewardship guidelines for judicious use of antibiotics, puts in place requirements for data collection on the use of

Table 1. Comparison of the Federal VFD Rule and California SB 27

	Federal VFD Rule	California SB 27
What products are regulated?	Medically-important antimicrobials	Medically-important antimicrobials
What product forms are regulated?	Feed- and water-based antimicrobials	All forms, including but not limited to, feed- and water-based antimicrobials, injectable, and intra-mammary
When can medically important antimicrobials be used?	Treatment, control, and prevention of disease	Treatment, control, and prevention of disease
When can medically important antimicrobials NOT be used?	Subtherapeutically (i.e., growth promotion, feed efficiency, etc.)	Subtherapeutically (i.e., growth promotion, feed efficiency, etc.) and cannot be used for prevention in a “regular pattern”

antibiotics, conducts surveillance for antimicrobial resistance, and surveys management practices and associated health outcomes.

Antibiotic Use Prior to Regulation

Each year the FDA reports on antimicrobials with antibacterial properties sold or distributed for use in food-producing animals. Although these data are the best that are currently available, they have inherent limitations, namely that they are sales to distributors and thereby do not necessarily account for volume of product purchased and used on animals. Further, many of these drugs are approved for both food- and non-food producing (i.e., companion) animals, such that an unknown quantity of these drugs are not entering the food-producing animal system. Figure 1 shows the total quantity of medically important antimicrobials sold and distributed for use in food-producing animals in the U.S. for the most recent five years.

According to the FDA, 97% of medically important antimicrobials sold and distributed for use in food-producing animals were available for sale over the counter in 2015. In the same

year, medically important antimicrobials accounted for 62% of total antimicrobial sales in the U.S., with tetracyclines and penicillins accounting for 71% and 10% of sales in this category, respectively. On a global scale, tetracyclines are also the most frequently reported class of antimicrobials used in animals. The World Organisation for Animal Health’s (OIE) 2016 Report on Antimicrobial Agents in Animals reports that 48% of sales in 89 member countries were in the tetracycline drug class.

Potential Economic Impacts of Antimicrobial Regulations

Restricting the use of antibiotics through regulations such as the federal VFD rule or SB 27 are likely to have economic ramifications in many segments of animal agriculture. And, while different species and life-stage-specific segments of the supply chain will be affected differently, farm-level production costs are predicted to increase. The costs associated with veterinary consults to facilitate the use of feed- or water-based antibiotic treatments will be borne by producers, with small operations likely experiencing higher costs on a per-unit basis. Further, the cost of feed-based

antibiotic treatment is likely to rise as feed mills and feed distributors are required to mix and sell medicated feeds in compliance with regulations, while engaging in more stringent record-keeping obligations. As producers substitute away from medically important antibiotics to unregulated alternatives, prices for these drugs may be driven up by increased demand.

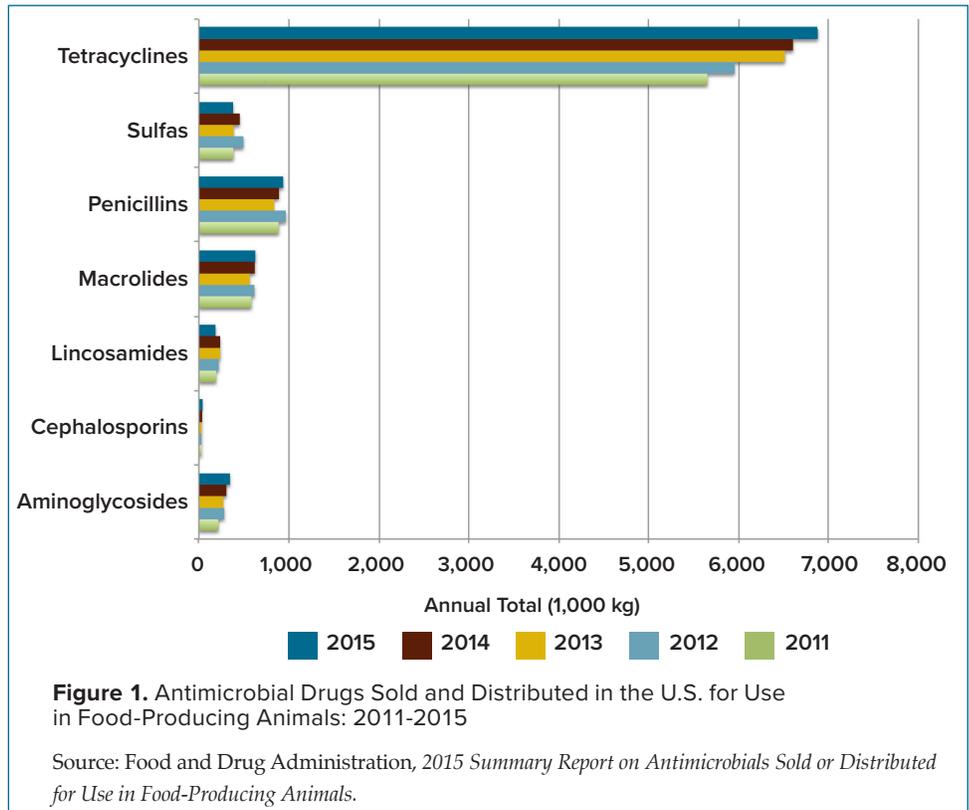
Further, producers with operations in remote locales may experience significant impediments when attempting to access veterinary services. Both the VFD Rule and SB 27 stipulate that for a veterinarian to provide a farmer/rancher with a VFD, they must have a veterinary-client-patient relationship (VCPR). FDA guidance indicates that a valid VCPR would require: i) that the veterinarian engage with the client (i.e., the animal producer) to assume responsibility for making clinical judgments about patient (i.e., animal) health, ii) have sufficient knowledge of the patient by virtue of patient examination and/or visits to the facility where the patient is managed, and iii) provide for any necessary follow-up evaluation or care. Limited access to veterinary services was a concern among many farmers and ranchers prior to these regulatory changes. In light of these new requirements, the demand for veterinarians with expertise in food-producing animal segments will likely rise, exacerbating shortages.

Antibiotics employed for growth promotion and to enhance feed efficiency are used in agricultural operations in order to reduce production costs per unit of meat and/or milk. Estimates based on the USDA Agricultural Resource Management Survey, analyzed by Sneeringer et al. (2015), suggest that producers using antibiotics in subtherapeutic settings will experience production cost increases of 1–2% if their access to antibiotics is restricted.

Further observational studies suggest that farmers will adopt alternative production practices in order to compensate for reductions in productivity resulting from restrictions placed on the use of antibiotics. For example, in production settings where animals are relatively confined (i.e., more animals per square foot of space), adopting enhanced sanitation practices may offset some of the production losses caused by eliminating the use of subtherapeutic antibiotics. These types of investments increase capital expenditures of these operations.

Finally, small market-level impacts should be anticipated as costs of production rise and some producers reduce production levels or exit the industry. Sneeringer et al. (2015) estimate that a 1–3% increase in production costs will increase wholesale prices by roughly 1% for a given level of output. These estimates are relatively small as not all producers or species at various life stages employ subtherapeutic antibiotic treatments.

Like other state-specific regulations that increase the regulatory burden and production costs of California farmers and ranchers, SB 27 will place those engaged in animal production in the state at a disadvantage relative to the rest of the U.S. if the use of subtherapeutic antibiotics was part of their production protocols. This is also likely true for the U.S. when competing with global trading partners. According to the World Organisation for Animal Health’s 2016 report, 74% of OIE member countries surveyed did not authorize the use of antimicrobials for growth promotion in animals. Yet, this report is silent on the identities of OIE members and so it is not possible to ascertain the strengths or weaknesses of those entities to determine likely trade impacts. Countries with high-profile antimicrobial regulations in place include Canada, the Netherlands, Denmark, and the



European Union broadly. To the extent that major U.S. trade competitors do not face similar restrictions on antimicrobial use in food-producing animals, the U.S. will be placed at a cost disadvantage in global markets.

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Suggested Citation:

Saitone, Tina L. “Economic Consequences of New Federal and State Regulations to Limit Antibiotic Use in Livestock.” *ARE Update* 21(1) (2017): 9–11. University of California Giannini Foundation of Agricultural Economics.

For additional information, the author recommends:

Sneeringer, S., J. MacDonald, N. Key, W. McBride, and K. Mathews. 2015. *Economics of Antibiotic Use in U.S. Livestock Production*. U.S. Dept. of Agriculture, Economic Research Service, Economic Research Report No. 200.

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Agricultural and Resource Economics

ARE UPDATE

Giannini Foundation of Agricultural Economics, University of California

Department of Agricultural and Resource Economics

UC Davis

One Shields Avenue

Davis CA 95616

GPBS

Agricultural and Resource Economics UPDATE

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Published by the

Giannini Foundation of
Agricultural Economics

<http://giannini.ucop.edu>

ARE UPDATE is published six times per year by the Giannini Foundation of Agricultural Economics, University of California.

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