GRASS-FED BEEF PREMIUMS

ABSTRACT

This study examines the grass-fed beef price premiums at the retail level for 12 various cuts as the difference and/or the ratio of grass-fed and conventional beef prices. We estimate the impact of consumer's income, consumption of food away from home, and the attitudes regarding environment, nutrition and taste on the premiums for each cut separately as well as a combined panel of all cuts. Results of the combined panel indicate that the grass-fed beef premiums are positively affected by the consumption of food away from home and consumers' attitudes regarding beef taste.

1. INTRODUCTION

In recent decades grass-fed beef has gained growing interest among American producers and consumers, especially among health-conscious consumers (McCluskey et al., 2005; Gillespie et al., 2016). Grass-fed is one of the production claims along with naturally raised, raised without antibiotics and/or hormones and certified organic that distinguish these products from conventionally raised grain fed beef. The U.S. grass-fed beef retail sales increased from less than $5 million in 1998 to $400 million in 2012 (Qushim et al., 2018; Williams, 2019). Bayless (2018) describes that "according to Nielsen data published in a report by the Bonterra Partners, retail sales of labeled fresh grass-fed beef doubled every year from 2012 to 2016, growing from $17 million to $272 million (Cheung and McMahon, 2017). While grass-fed beef market has been growing, it still remains fairly small. In 2019, only about 4% of total sales were marketed with some type of label claim with grass-fed category amounting to 1.82% of total retail beef volume.[1]

Although in 2020 the world suffered from COVID-19 pandemic, the grass-fed beef remained its prosperity, or even better. Evidence from Meatingplace showed during the COVID-19 pandemic, meat demand increased compared to the year 2019 (Meatingplace, 2020). Particularly in cattle sector, the U.S. witnessed an additional $4.0 billion sales for cattle from mid-March to late August in 2020, at least 2 more million than the increase in sales of other meat such as chicken and pork. Also, beef has covered the second largest percentage of the protein consumption since late June. Moreover, grass-fed beef was proved to receive the highest gains with a rise of 64.3%, higher than other claims-based meat such as organic and antibiotic meat (Meatingplace, 2020). In short, grass-fed beef is now playing a more important role in meat market than ever before.

Consumer interest in grass-fed beef is motivated by the beliefs that it offers some nutritional advantages and is more environmentally friendly than conventional grain-fed beef. Bayless (2018) describes that "several consumer beliefs about the health benefits of grass-fed beef include less total fat content, better omega-6 and omega-3 fatty acid ratio, higher levels of antioxidants, a lower risk of E. coli infection, and higher levels of Conjugated Linoleic Acid (CLA)" (Cheung and McMahon, 2017). Another priority for consumers, especially those concerned with both health and animal welfare, is the use of growth-inducing, sub-therapeutic antibiotics and hormones. A study conducted by Consumer Report comparing multi-drug resistant samples in grass-fed and conventional beef, grass-fed beef had three times lower likelihood of containing multi-drug resistant bacteria (Consumer Reports, 2015). Consumers are also often concerned about environmental stewardship. A recent

[1] See https://www.beefitswhatsfordinner.com/retail/sales-data-shopper-insights/options-at-retail

wave of information highlighting the regenerative aspects of grass-fed grazing has further prompted consumer interest. If managed properly, grass-fed grazing has been shown to improve soil quality, promote the growth of healthy grasses, and sequester carbon in the ground to mitigate climate change (Shinn and Pledger, 2017). Another reason for the increase in demand may partially result from the unique taste and flavor of grass-fed beef. This pertains to relatively few customers and is most prevalently found in the opinions of chefs and connoisseurs. Grass-fed cattle of the right breed, produced to high standards, can result in beef that is more tender, well-marbled and, in the opinion of many connoisseurs, better-tasting than grain-fed beef (Cheung and McMahon, 2017). Achieving this quality of grass-fed meat is rare, and it is important to note that few consumers are buying just for the flavor, and many would still prefer the flavor of conventional beef over grass-fed. Ironically, higher marbling (better flavor) may reduce the health benefits of consuming grass-fed beef.

This growth in the grass-fed beef markets precipitated a number of studies focusing largely on the production aspects of grass-fed beef markets as one of the biggest challenges is to profitably produce a high-quality tender beef that is also healthy and environmentally friendly. Many grass-fed producers raise smaller-framed cattle that mature early; however, smaller framed cattle must be able to reach a live-weight of 1,100 pounds to grade well, which is challenging to achieve without proper genetics (Rinehart, 2006). Mathews & Johnson (2013) explored the production technologies behind various beef production systems. The results implied that the markets change as consumers' demand changes and as science and knowledge converges. Gillespie et al. (2016) demonstrated that farm experience, farm size and production system could affect the marketing channel choices of grass-fed beef producers. Qushim et al. (2018) examined the technical and scale efficiencies of grass-fed beef production using the data of the mail survey of 1050 U.S. grass-fed beef producers during August-September 2013. The results illustrated that the grass-fed beef farm would be efficient if the optimal size of production was larger than 100 animals.

Among the grass-fed beef demand studies, Cheung and McMahon (2017) concluded that baby boomers and others who care about health and fitness are also likely buyers of grass-fed beef. A 2014 survey by the Consumer Reports National Research Center also showed that when shopping for food, consumers feel that it is important that their purchases "support local farmers, protect the environment, support companies that treat workers well, provide better living conditions for animals, and reduce the use of antibiotics." (p.6 Consumer Reports, 2015) According to a study conducted in Portland, Oregon, a baseline, uninformed consumer will pay \$0.90-\$0.94/pound more for grass-fed ground beef; knowledge about production and nutritional factors increase the premium (Gwin et al., 2012)." In the study of Umberger et al. (2002), 23% of the American consumers were willing to pay a premium of \$1.36 per pound for the Argentine grass-fed beef against U.S. grain-fed beef. Tonsor et al. (2018) found that media reports, especially those related to climate change, could affect the meat demand.

To the best of our knowledge, little is known about how premiums for grass-fed beef vary across different cuts of meat and what factors affect these premiums. Our study will use data from the Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture (USDA) to examine the premiums for grass-fed beef across 12 different cuts of beef over 2014-2019 and the factors that affect these premiums.

2. BEEF PRICES

Monthly price data for 16 different cuts of grass-fed beef from 01/2014 to 12/2019 were collected from the National Monthly Grass Fed Beef Report published by USDA-AMS. Monthly price data for conventional beef over the same time period were obtained from the National Retail Beef Activity Report, also published by USDA-AMS.

Grass-fed beef prices in November and December 2014 were not available due to seasonal product limitations. Several cuts, including, ribeye roast, bottom round roast, tri tip and sirloin roast had additional missing values and were not included in the estimation, leaving 12 beef cuts as a focus of this research. The values in November and December 2014 are replaced by the values in October 2014. Other missing data at period *t* are replaced by the value at period *t-1*.

An important change took place during the period of study when USDA revoked the "USDA Grass-fed" label on January 12, 2016, while leaving the standards for the claim[1] on their website for producers to follow (USDA-AMS, 2016). At the same time, the USDA Grass Fed Small and Very Small Producer Program (SVS) administered by AMS remained intact and the AMS continued to collect and disseminate price information for meat products labeled grass-fed.

We assess price premiums for grass-fed beef in $/lb units:

$$PD = P_{GF} - P_{CB}, \tag{1}$$

where PD denotes the difference between grass-fed beef price P_{GF} and conventional beef price P_{CB}. This measure is straight forward and easily traceable to changes in its components, but it does not consider the original price levels of various cuts. An alternative grass-fed premium measure is a price ratio:

$$PR = P_{GF}/P_{CB}, \tag{2}$$

where PR, denotes the ratio of grass-fed beef prices over conventional beef prices and represents a proportional difference between the two.

[Figure 1 here]
[Table 1 here]

Figure 1 shows the grass-fed beef prices and conventional beef prices over the period Jan/2014-Dec/2019. It indicates that grass-fed beef prices are larger than conventional beef prices in most times. Table 1 shows that beef prices varied significantly across cuts. Filet mignon, tenderloin and ribeye steak were the most expensive cuts for both conventional ($13.60/lb, $11.19/lb, and $8.56/lb, respectively) and grass-fed beef ($35.19/lb, $30.11/lb, and $22.07/lb, respectively). However, the cheapest cuts were slightly different with rump roast ($3.99/lb) and short ribs ($7.89/lb) being the cheapest cuts for conventional and grass-fed beef, respectively. Grass-fed beef tends to be leaner than conventional which makes it more attractive for some cuts but not for others. Therefore, price differences between conventional and grass-fed beef are not always consistent with whether the cuts are cheaper or more expensive in the conventional beef market.

[Figure 2 here]

[1] See https://www.ams.usda.gov/services/auditing/grass-fed-SVS

Figure 2 shows the price premiums of twelve beef cuts (solid line, left y-axis). Filet mignon and tenderloin have the largest range of premiums. Table 1 shows that the largest price differences in $/lb were observed for the three most expensive cuts, filet mignon ($21.60/lb), tenderloin ($18.92/lb) and ribeye steak ($13.51/lb), but the next largest difference of $10.54/lb was for sirloin steak, a much cheaper cut in the conventional beef market. However, when price differences were assessed as a ratio, sirloin steak had the largest premium at 2.95 times followed by tenderloin (2.79), filet mignon (2.66) and ribeye steak (2.60). Thus, it appears that sirloin and the premium steaks were the most valuable cuts of grass-fed beef.

Less expensive steaks, such as flat iron steak (2.21), flank steak (1.78), and skirt steak (1.74) had relatively smaller premiums with flat iron steak being the most valuable cut of grass-fed beef in this category with significantly higher premiums in both $/lb and proportion terms. Even though roasts were some of the cheapest cuts of beef, they generated substantial premiums in the grass-fed beef market, from 2.07 ($4.29/lb) for chuck roast to 2.38 ($5.33/lb) for rump roast. On the other hand, stew meat and short ribs generated some of the lowest premiums in the grass-fed market suggesting that these were less attractive cuts in the grass-fed market.

[Table 2 here]

We explored the trends and seasonality in grass-fed premiums measured as price ratios in Table 2. OLS coefficient estimates for constants are consistent with the descriptive statistics shown in table 1 and describe average price ratios.

Monthly trend estimates suggest that grass-fed price premiums were decreasing for Filet mignon and short ribs, with the most expensive and one of the cheapest cuts becoming less valuable in the grass-fed market. On the other hand, price ratios for ribeye steak, rump roast, chuck roast, skirt steak, flat iron steak, and flank steak premiums have been increasing slowly over time. While most price ratios do not exhibit significant seasonality, relative prices of some cuts vary across months. Some cuts of grass-fed beef, such as filet mignon and brisket become more valuable during the summer months (May-August) while others, such as flank steak and chuck roast become less valuable during this time. Additionally, premiums for grass-fed tenderloins tend to increase in March, ribeye steaks in February, filet mignons in December and short ribs in July, November and December. Our findings for premiums measured as price differences were very similar.[1] Examination of stationarity in the grass-fed beef premiums measured as price differences and price ratios using augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1981) and Phillips-Perron (PP) test (Phillips & Perron, 1988) summarized in table 1 revealed that many of these series were non-stationary, which may result in spurious regression in the empirical analysis.

In order to eliminate seasonal patterns and decrease the presence of non-stationarity we transformed our measures of price premiums to annual changes. Specifically, the year-to-year changes in premiums measured as $/lb differences are specified as

$$\Delta PD = PD_t - PD_{t-12} = \left(P_{GF,t} - P_{CB,t}\right) - \left(P_{GF,t-12} - P_{CB,t-12}\right), \quad (3)$$

[1] Results are not presented here but available from the authors upon request.

where PD_t and PD_{t-12} denote the differences between grass-fed beef prices and conventional beef prices at *t* period and *t-12* period respectively. Similarly, we measure annual changes in premiums measured as price ratios as

$$\Delta PR = PR_t - PR_{t-12} = \left(P_{GF,t}/P_{CB,t}\right) - \left(P_{GF,t-12}/P_{CB,t-12}\right), \tag{4}$$

where all variables are as described above. We also develop a new method measuring the annual changes by using the annual difference ratio, derived from annual difference of price difference divided by the lagged price difference ($\%PD$), specified as

$$\%PD = \left(\frac{PD_t - PD_{t-12}}{PD_{t-12}}\right) = \left(\frac{PD_t}{PD_{t-12}}\right) - 1 \tag{5}$$

where all variables are also as described above. In this paper we will focus on the year-to-year changes in price difference (ΔPD) and the remaining estimation results for the annual difference of price ratio will be attached in Appendix.

[Table 3 here]

Figure 2 also shows the graphs of the annual difference of price difference (dashed line, right y-axis). The plots show that for most beef cuts, the curve of annual change of price premiums have similar trends as the price premiums, but in different values. Table 3 shows the descriptive statistics and unit root tests of the annual difference of grass-fed price differences and grass-fed price ratios. Particularly, Table 1 shows that the largest year-to-year change in price differences are filet mignon ($-1.054/lb) in terms of absolute values, followed by skirt steak ($0.685/lb) and rump roast ($0.32/lb). The other beef cuts have the annual change in grass-fed price difference less than $0.31/lb. Grass-fed price difference for brisket and stew meat increase $0.017/lb and $0.023/lb respectively every year, much slower than other beef cuts.

If price differences are evaluated as price ratio, the magnitude of annual change will be much smaller for all beef cuts. Measured in magnitude, rump roast has the largest annual movement in price ratio (0.103) followed by filet mignon (-0.084), skirt steak (0.064) and ribeye steak (0.061). Sirloin steak and stew meat are the lowest two cuts in terms of annually price ratio change, annually increasing by 0.002 and 0.004 respectively. In short, although the least annual changed cuts measured in price difference are to some extent different from those measured in price ratio, it shows that filet mignon, rump roast and skirt steak have the largest annual movement in price premiums.

In short, Table 3 has shown beef cuts have large differences in means and variance of price differences, price ratios, the annual difference of price difference and ratios. Table 2 shows that the seasonal effects on beef premium vary by beef cuts. Both facts imply that the property of price premiums might be also largely different across the cuts. Moreover, any further model specifications for grass-fed price premiums might also very by beef cuts.

Table 3 also show divergent unit root test results of the price difference and price ratios using augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1981) and Phillips-Perron (PP) test (Phillips & Perron, 1988). Results indicate that despite rejecting nulls of unit roots with one lag for all cuts, most of ADF tests fail to reject the null with more lags the price differences and price ratios. On the other hand, PP tests reject the null of unit roots for all beef cuts. Since failure to reject the null does not suggest the existence of a unit root, ADF and PP tests may not tell apart a unit root and weakly stationary alternatives (Xu, 2020). Therefore, we also implement Kwiatkowski, Phillips, Schmidt, Shin (KPSS) tests (Kwiatkowski et al., 1992). The results show KPSS tests fail to reject the null of stationary for all annual change of price difference and price ratio at the 5% significant level. Therefore, we conclude that while price premiums are nonstationary in levels for some cuts, they are stationary in annual changes for all beef cuts at the 95 confidence levels.

3. CONCEPTUAL FRAMEWORK

Economic theory often assumes that consumers receive perfect information and purchase decision are based on the income, preferences and tastes. However, consumers usually do not obtain perfect information that alter their preferences (Rieger et al., 2016). Reports from USDA show that grass-fed beef now is more popular among the U.S. consumers than before, indicating the varying preferences or taste among the consumers over time (Mathews & Johnson, 2013). In addition, data from U.S. Bureau of Economic Analysis shows that the Americans have growing disposable income per capita since the 1950s. This hence brings to our concern that the information and consumers' income as well as preferences might alter consumers' purchase decisions on grass-fed beef products.

Claims-based food refers to the foods with specific attributes such as organic, GMO-free and grass-fed. Price premiums measure the consumers' willingness to pay for a claims-based food rather than the conventional food. Previous studies have used price difference (Wang et al., 2008) and percentage price change (Steenkamp et al., 2010) as forms of price premiums.

A traditional research to illustrate the consumers' preferences on claims-based food is to measure their willing to pay (WTP) using the data from interviews, written surveys, and experimental auctions (Umberger et al., 2002; Steenkamp et al., 2010; Alphonce & Alfnes, 2012; Lim et al., 2013). Using this method, for years researchers have found some factors that could influence the demand for claims-based products, and, ultimately, change their price premiums (Umberger et al., 2002; Alphonce & Alfnes, 2012).

Meanwhile, various studies research on beef prices using the hedonic models (Wahl & Mittelhammer, 1995; Parcell & Schroeder, 2007; Ward, Lusk & Dutton, 2008; Schulz, Dhuyvetter & Doran, 2015). Hedonic analysis examines the good prices by including exhaustive list of product attributes (Ward, Lusk & Dutton, 2008). However, this method not only excludes the consumers' motivation to purchase the food, but also needs various survey data. Since our premium data are at the national level, using survey data to estimate their impacts on price premium will cause a biased estimation. This study will stand from consumers' standpoint and use the independent variables at the national level to examine their impacts on grass-fed premiums.

Disposable income has been shown to positively affect premiums in other niche markets, such as organic food (Smith et al., 2009; Alphonce & Alfnes, 2012). Smith et al. (2009) showed that higher income raises the probability of paying the premium of organic vegetables and fruits against traditional food. Alphonce & Alfnes (2012) indicated that consumers in Tanzania with higher income will pay more for the organic tomato.

Consumer preferences for grass-fed beef products would also increase such premiums. In the study of Umberger et al. (2002), 23% of the American consumers were willing to pay a premium of $1.36 per pound for the Argentine grass-fed beef against U.S. corn-fed beef. Alphonce & Alfnes (2012) found that consumers have a preference to inspected and organic tomato and would significantly pay a premium for them no matter how much incomes they have. Those two studies used WTP to evaluate consumer preferences, but they failed to discuss the motivations behind consumer preferences.

Some factors are likely to affect the niche markets, but their impacts haven't been examined by any quantitative methods yet. Food away from home (FAFH) is an example. The away from home market consists of take-away food, eating food in restaurants and institutions such as schools and government organizations (Pearson et al., 2010). Research found that although nutrient composition varies across the source of food away from home over time, individuals generally consume less healthful foods when eating away from home (Todd et al., 2010; Saksena et al., 2018). Moreover, people do not compensate for less nutritious food away from home by eating healthier food at home (Todd et al., 2010). Since the grass-fed beef is healthier than the conventional beef, we infer that the consumption of food away from home might alter the grass-fed price premium.

Meanwhile, previous studies also found that the media and medical information was the demand determinants of beef (Tonsor et al., 2010; Tonsor et al., 2018). The consumer's environmental concerns, such as the people's views toward climate change, can affect the grass-fed beef demand (Tonsor et al., 2018). Tonsor et al. (2018) made a rank for factors affecting steak and ground beef demand. Results showed the political ideology, including opinions of global warming and climate change, is one of the top six impact factors for the demands for both steak and ground beef. However, yet no empirical research found the impact of such political ideology on the grass-fed beef price premium.

The belief of nutrition in grass-fed beef and beef taste can also affect beef demand (Tonsor et al., 2010; Tonsor et al., 2018). Tonsor et al. (2010) found taste and nutrition are important indexes in beef demand. In particular, medical journal articles linking nutrition such as iron, zinc, and protein is positively linked to beef demand. In other words, more publications in such nutrition elements can lead to more purchase in beef. Meanwhile, the research has also found that the number of published articles related to fat negatively affects beef demand. On the other hand, Tonsor et al. (2018) used a food demand survey called FooDS survey from 2013 to 2017 and found food taste was the most important food value and nutrition was the fourth important food value.

The revocation of "grass-fed" label in January 2016 hits the grass-fed beef markets. The revocation means ranchers and restaurants can become the third party certifying grass-fed beef. Some ranchers and restaurants were found to label their conventional beef products as grass-fed. This leads to various misleading marketing of grass-fed beef products (Wilford, 2016). However, yet it's unknown whether the misleading marketing leads to the higher relative prices of grass-fed beef products.

Previous studies research on the consumer preferences using survey responses or experiment results based on consumers' intentions, or using organic food uses data on the actual purchases of organic food (Steenkamp et al., 2010; Lusk, 2011). To the best of our knowledge, none of them has ever used macro data to estimate the impact of income or consumer preference on grass-fed beef price premiums.

Apart from those factors we mentioned above, endogenous factors also influence the grass-fed beef price premiums. For example, based on the economic theories, the quantity of grass-fed beef and conventional beef at the retail level can also affect the both grass-fed beef price and conventional beef prices. To simplify our study, we will not take the effects from those endogenous factors into account. We will use reduced form equation, which is derived from a system of linear simultaneous equations and expresses the dependent variables as a linear function of all of the exogenous variables and an error term (Wooldridge, 2010). Previous research has widely used reduced form to examine the impacts from exogenous variables (Contoyannis & Jones, 2004; Wooldridge, 2010; Goodwin, 2015; Mason et al., 2017). Contoyannis & Jones (2004), for example, derived reduced forms for the healthy style equations and examined how self-assessed health is affected by various exogenous variables such as part-time work. Mason et al. (2017) used reduced forms to estimate various exogenous effects, age of household head for example, on endogenous variables such as the percentage of smallholder household received Fertilizer Support Program. Our research will further make reduced form models, collect macro data of disposable income, food away from home, beef taste and environmental and nutritional information and examine their impacts on grass-fed price premiums.

Our reduced form price premium models will be derived from the structural grass-fed beef price and conventional beef price equations. That's to say, we have an equation for grass-fed beef price

$$P_{GF} = f(X, Y), \tag{6}$$

and an equation for the conventional beef price,

$$P_{CB} = g(X, Z), \tag{7}$$

where P_{GF} and P_{CB} are the same as those in equation (1) and (2); X denotes the matrix including those variables simultaneously affecting grass-fed beef prices and conventional beef prices; Y and Z denote the matrix of exogenous variables affecting grass-fed beef price and conventional beef price, respectively. Based on equation (6) and equation (7), we can derive the reduced-form equation (8)

$$PP = h(Y, Z), \tag{8}$$

where PP is the grass-fed beef price premium, which can be specified as either the difference of grass-fed beef price and conventional beef price (PD), or price ratio of grass-fed beef on conventional beef (PR). The only independent variable in equation (8) are various exogenous variables that affect the grass-fed beef price and the conventional beef price differently, including Y, W and Z.

Since the property of grass-fed price premium is different among beef cuts, we will establish an individual model for each beef cut using the grass-fed price premium specifications (3) and (4) to explain the effects caused by exogenous variables. As discussed, since the seasonal patterns are captured in price differences and price ratios, we will use the annual change of price premiums specified in equation (3), (4) and (5). To keep the variables in levels or in ratio forms, we set up two equations, i.e.

$$\Delta PD_{i,t} = \boldsymbol{a}_i'\boldsymbol{A} + b_i REV_t + c_i t + \epsilon_{i,t}, \tag{9}$$

and

$$\Delta PR_{i,t} = \boldsymbol{\alpha}_{\boldsymbol{i}}'\boldsymbol{B} + \beta_i REV_t + \gamma_i t + \varepsilon_{i,t}, \tag{10}$$

and

$$\%PD_{i,t} = \boldsymbol{\varphi}_{\boldsymbol{i}}'\boldsymbol{B} + \omega_i REV_t + \tau_i t + e_{i,t}, \tag{11}$$

where ΔPD_i and ΔPR_i denote the annual difference of grass-fed price difference and ratio respectively. $\boldsymbol{A}$ denotes the matrix with exogenous variables in annual difference of original forms; $\boldsymbol{B}$ denotes the matrix with exogenous variables in annual difference of logarithm forms; REV_t denotes the dummy for the revocation of "grass-fed" label by USDA in January 2016, with the value 0 for the months before January 2016 and 1 for January 2016 and the months after; t denotes the monthly trends from January 2015 to December 2019. The parameters $\boldsymbol{a}_i$ captures the impact of the annual difference of exogenous variables in original forms; $\boldsymbol{\alpha}_i$ and $\boldsymbol{\varphi}_i$ capture the impact of the annual difference of exogenous variables in logarithm forms on the annual difference of grass-fed price premiums for price ratios and the percentage change of price differences; the parameter b_i, β_i and ω_i capture the impact of the revocation of the grass-fed label on price premiums; c_i and γ_i denote the time effect in equation (9) and equation (10); ϵ_i, ε_i and $e_{i,t}$ denote the error terms.

Model (9) and (10) estimate the effect of independent variables on price premium of each beef cut using OLS regressions. However, the general impact of income, FAFH and medical news and information on all the beef cuts are still unknown. Therefore, we estimate that general effect by treating all the beef cuts as a panel.

4. DESCRIPTIVE STATISTICS

Monthly real disposable personal income is the Real Disposable Personal Income Per Capita published by U.S. Bureau of Economic Analysis. We collected the data from Federal Reserve Economic Data (FRED) at the Federal Reserve Bank of St. Louis. The data is in chained 2012 dollars and seasonally adjusted by X-13ARIMA-SEATS, which is a seasonal adjustment software developed by the U.S. Census Bureau.

To measure the relative FAFH sales against people's income, we will use the ratio of nominal FAFH sales on nominal disposable personal income as an indicator of FAFH. The monthly sales of food away from home are collected from the United States Department of Agriculture, Economic Research Service (USDA-ERS). Nominal personal income is also collected from FRED.

We follow the approach of Tonsor et al. (2018) to measure the environmental concerns, beef taste, and nutritional information using media and medical information. Specifically, environmental information includes news related to climate change in agriculture. Nutritional information includes the published literature in the topics of zinc, protein and fat in beef. The news associated with climate change and beef taste will be collected from NewsBank. The published literature related to beef protein and beef fat is collected from PubMed. Data sources and the keywords for searching are shown in Table 4.

[Table 4 here]

[Table 5 here]

Table 5 indicates the descriptive statistics of the annual difference of both original and log-formed explanatory variables. The median transition of real disposable income is $1,054.13 per capita for original forms and 0.025 per capita for log-form. The annual transition of the ratio of restaurant spending on disposable income is equal to 0.49 on average. In medical news and information, the annual transition of climate change news has the largest magnitude in original forms ($62.50) and in logarithm forms (0.084) while fat has the lowest magnitude of annual change in terms of original forms ($-0.45). Table 5 also shows the unit root tests for independent variables in the annual difference of original forms and logarithm forms. It indicates climate change, taste, protein and fat are stationary in both original forms and logarithm forms while stationarity of other variables are unclear since Phillips-Perron tests and KPSS tests draw controversy conclusions.

5. EMPIRICAL RESULTS

[Table 6 here]

Table 6 shows OLS estimation results of the impact of explanatory variables on grass-fed beef premiums measured as price differences. F tests imply that our model estimations are not statistically significant for ribeye steak, flat iron steak and flank steak, which is also supported by the adjusted R-squared statistics. Therefore, we focus our discussion of results on the remaining cuts. Our coefficient estimates for constants suggest that annual changes in price premiums were not significantly different from zero in most of the cases but marginally significant for skirt steak at 4.6 $/lb and for filet mignon at 7.3 $/lb. Our findings the trend indicate that annual changes in rump roast, brisket and chuck roast premiums decreased over time becoming less variable.

Increases in consumer's disposable incomes lead to increases in premiums for grass-fed beef sirloin steak and rump roast, but decreases in premiums for skirt steak suggesting that it may be viewed as an inferior cut. Greater consumption of food away from home will not alter the premiums for the remaining cuts significantly.

Consumers' environmental concerns appear to be the biggest driver for grass-fed beef price premiums. In particular, when consumers become more concerned about climate change, premiums for grass-fed beef cuts of filet mignon, tenderloin, rump roast, brisket, chuck roast, stew meat and short ribs tend to grow. The estimates also show that people will also comparatively pay less grass-fed skirt steak given less perceptions in climate change.

Increased consumer attention to beef taste information leads to larger premiums for grass-fed tenderloin. In addition, consumers' growing concerns in protein result in a rise in premium for grass-fed tenderloin and stew meat. When consumers learn more about beef fat knowledge, premiums for grass-fed brisket is lower and for sirloin steak is higher. The revocation of grass-fed labels brings to a lower premium for filet mignon and a higher premium for brisket.

[Table 7 here]

Table 7 shows the estimations of the beef cut panel. Serial correlation tests discussed by Wooldridge (2010) and Drukker (2003) suggest that the idiosyncratic errors don't have any autocorrelation problems. We firstly use pooled OLS with dummies of each beef cut in estimations (column 1). The F-tests tests of the entity-specific intercepts indicate a statistically insignificant individual term for all the beef cuts[1]. This implies that the annual differences of price differences are very similar across beef cuts. Therefore, we don't estimate any individual-specific–effects models such as fixed effect models and random effect models. Results in column 1 indicate that consumers' higher consumption away from home leads to more payments in grass-fed beef price premiums. Consumers' increasing perceptions on climate change, beef taste and protein will bring to a higher grass-fed beef price premium. If consumers have higher income, they will relatively pay less grass-fed beef cuts, but this effect is imprecisely estimated so that it's statistically insignificant. The estimates also show that consumers' rising attention to fat in beef and the revocation of the grass-fed label will not significantly lead to the fall of the grass-fed price premium.

Since the F-tests of individual intercept term imply the annual differences of price difference are similar across beef cuts, we assume the disturbances are heteroskedastic and contemporaneously correlated across beef cut panels. We then estimate the panel model using pooled OLS estimators with panel-corrected standard errors as shown in column 2. Column 2 shows that the estimated coefficients are the same as pooled OLS estimates with beef cut dummies, but the estimators have larger standard errors in magnitude.

In column 3 we estimate the effects using a pooled feasible GLS with a heteroskedastic error structure with cross-sectional correlation. The pooled feasible GLS estimators are more efficient asymptotically than pooled OLS estimators. Pooled feasible GLS estimates show a consistent result as pooled OLS estimates in column 1 and column 2. A larger consumption in restaurant results in a higher payment for grass-fed beef products. Increased consumers' concerns in climate change and beef protein leads to a rise in the grass-fed beef premium. The change of consumers' income and consumers' perception in beef fat will not significantly alter the grass-fed beef premium.

Sensitivity Analysis

We check the robustness of regressors using price ratios and the logarithm forms of independent variables. Table A in Appendix shows the OLS estimations for each individual cut. F tests show that the model specifications are statistically insignificant for filet mignon, sirloin steak, ribeye steak and flank steak. The estimates show consistent results as the estimates of price differences in Table 6.

We also estimate the effect on price ratios by regarding the beef cuts as a panel. The F-tests of individual terms in pooled OLS estimates with cut dummies suggest that the twelve beef cuts have similar annual differences of price ratios. We hence don't estimate the model using individual-specific–effects models. However, the autocorrelation of the idiosyncratic errors is detected by the panel serial correlation. In this case, OLS estimates won't provide a consistent estimate. Therefore, we estimate equation (9) using a pooled feasible GLS with an autocorrelation AR(1) process that is common to all the panels. Results suggest that if variables are specified in logarithm forms, a higher consumers' disposable income can significantly lead to a decrease in grass-fed beef price. The effects of other independent variables on grass-fed price differences are consistent with the estimations on grass-fed price ratios in Table 7.

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[1] Despite not showing in Table 7, fixed effect estimates got the same estimates as pooled OLS with cut dummies in terms of coefficients and standard errors. The F-tests of individual intercept term in fixed effect estimates also fail to reject the null that the individual-specific effects are equal to zero.

Table B in Appendix estimates the impacts of factors on the percentage of price difference. The results are consistent with Table A. For the individual cut, F-tests of OLS estimations show that the model specifications are meaningful for filet mignon, tenderloin, rump roast, chuck roast, skirt steak, stew meat and short ribs. For the beef cut panel, F-tests of individual terms in pooled OLS estimates with cut dummies failed to reject the null, resulting in the rejection of individual-specific–effects models. The serial correlation tests show that the error term has a correlation problem. Therefore, we use a pooled feasible GLS with an autocorrelation AR(1) structure. Cut panel estimates show that the mean of grass-fed price premiums is equal to 0.2585 without taking other effects into account. Consumers' rising concerns in climate change and protein lead to an increase in grass-fed price premiums. Other beef cut panel effects are not precisely estimated and hence statistically insignificant.

6. CONCLUSION

Our findings have a strong potential of generating a discussion on grass-fed beef premiums. Specifically, we discussed to what extent the real disposable income per capita, consumers' eating habit and medical and media information explain the grass-fed beef premiums. We found that the grass-fed price premiums vary in the levels but are similar in the annual differences for twelve beef cuts.

As the grass-fed beef industry continues to grow, our findings will help beef retailers understand the effects of income, consumers' eating habit and environmental and medical concerns on grass-fed beef price premium. In addition, during the pandemic of COVID-19 grass-fed beef gained most among the claims-based meat. Our paper could enhance the gains of grass-fed beef in the meat market. Particularly, when the people's disposable income increases, the grass-fed beef industry and retailers can gain more revenue by advertising more grass-fed sirloin and rump roast. Meanwhile, since the checkoff programs in the U.S. are funded by industry stakeholders and help advertise campaigns[1], grass-fed beef producers can pool resources to promote climate change, beef taste and beef protein.

Our research implies that the reopening of the restaurant during the pandemic of COVID-19 will not only attract more consumers and recover the economy, but also improve the grass-fed beef premiums. In other words, a withdrawal of lockdown by the state government can finally result in an increase in grass-fed beef price premium. Restaurant owners can prepare more grass-fed beef products when they are ready to reopen.

USDA-AMS calculated the monthly GFB price by arithmetically averaging the prices of the second and third week given four weeks in one month. This derivation ignores the price of the first week and fourth week, which possibly resulting in inaccuracy if any shock happens at the beginning of or at the end of one month. Further studies could study if those shocks ever exist and to what extent influence the reported monthly grass-fed prices. Moreover, our study focuses on the impact of exogenous variables on the grass-fed price premiums. Further studies can analyze the linkage of the price premiums between different cuts.

[1] See https://www.usda.gov/media/blog/2011/09/21/industry-insight-checkoff-programs-empower-business

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Table 1 Descriptive statistics for monthly prices and premiums for various cuts of conventional and grass-fed beef, 2014-2019

		Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
	Abr.	FM	Te	SiS	RS	RuR	Bri	CR	SkS	FI	FS	SM	ShR
Conventional Price ($/lb)	Mean	13.60	11.19	5.57	8.56	3.99	4.28	4.29	7.51	6.84	7.78	4.75	5.09
	Median	13.91	11.27	5.46	8.38	3.90	4.01	4.18	7.47	6.86	7.63	4.75	5.10
	Std. Dev.	2.00	1.69	0.87	0.84	0.60	1.20	0.51	1.44	0.65	0.89	0.27	0.39
Grass-fed Price ($/lb)	Mean	35.20	30.11	16.11	22.07	9.32	9.14	8.78	12.32	14.96	13.74	9.23	7.85
	Median	34.65	28.97	15.89	22.07	9.46	9.20	8.80	12.30	14.66	13.70	9.12	7.76
	Std. Dev.	5.19	5.57	2.00	2.02	0.76	0.58	0.48	1.64	1.62	1.24	0.86	0.63
Price Differences ($/lbs)	Mean	21.60	18.92	10.54	13.51	5.33	4.86	4.49	4.81	8.12	5.96	4.47	2.76
	Median	20.90	17.84	10.32	13.80	5.57	5.13	4.65	5.14	7.98	6.13	4.34	2.65
	Std. Dev.	5.64	5.68	2.03	2.05	1.07	1.36	0.69	2.47	1.72	1.31	0.82	0.72
	ADF test with 1 lag	-5.983***	-4.178***	-5.823***	-4.342***	-5.427***	-4.480***	-4.712***	-3.719**	-4.175***	-6.249***	-4.951***	-4.537***
	ADF test with 4 lag	-2.343	-3.186*	-3.201*	-2.947	-3.056**	-3.175*	-3.041	-3.001	-3.281*	-3.262*	-2.219	-2.722
	ADF test with 8 lag	-2.061	-2.413	-2.411	-2.650	-2.831	-1.473	-2.610	-2.783	-3.044	-2.723	-2.935	-2.019
	ADF test with 12 lag	-2.224	-2.368	-4.485***	-3.146	-1.920	-0.963	-2.444	-1.879	-2.310	-1.398	-3.599**	-2.685
	PP with trends	-6.083***	-6.531***	-6.893***	-7.754***	-5.658***	-7.228***	-5.725***	-6.186***	-7.134***	-7.199***	-5.287***	-6.134***
	PP without trends	-5.641***	-6.518***	-6.921***	-7.428***	-4.762***	-7.264***	-5.097***	-4.489***	-6.274***	-5.648***	-5.141***	-4.837***
	KPSS with trends	0.116	0.0809	0.0897	0.0596	0.128*	0.174**	0.129*	0.0992	0.0822	0.103	0.0731	0.0895
	KPSS without trends	0.314	0.114	0.132	0.339	0.538**	0.189	0.459*	0.505**	0.396*	0.585**	0.183	0.452*
Price Ratios	Mean	2.66	2.79	2.95	2.60	2.38	2.28	2.07	1.74	2.21	1.78	1.94	1.55
	Median	2.50	2.57	2.94	2.59	2.45	2.33	2.13	1.69	2.16	1.80	1.93	1.52
	Std. Dev.	0.65	0.91	0.53	0.32	0.36	0.56	0.22	0.62	0.32	0.20	0.19	0.16
	ADF test with 1 lag	-5.983***	-4.178***	-5.823***	-4.342***	-6.126***	-5.168***	-4.513***	-4.340***	-4.156***	-6.124***	-6.405***	-4.671***
	ADF test with 4 lag	-2.343	-3.186*	-3.201*	-2.947	-2.968	-3.004	-3.106	-2.995	-3.320*	-3.516**	-2.407	-2.665
	ADF test with 8 lag	-2.061	-2.413	-2.411	-2.650	-2.156	-1.208	-2.126	-2.759	-3.255*	-2.753	-2.957	-2.083
	ADF test with 12 lag	-2.224	-2.368	-4.485***	-3.146	-0.568	-1.085	-1.354	-1.995	-2.367	-1.511	-3.901**	-2.503
	PP with trends	-6.083***	-6.531***	-6.893***	-7.754***	-6.774***	-7.090***	-6.166***	-5.814***	-6.669***	-7.416***	-5.431***	-6.174***
	PP without trends	-5.641***	-6.518***	-6.921***	-7.428***	-5.386***	-7.124***	-5.425***	-5.519***	-6.377***	-6.416***	-5.321***	-4.672***
	KPSS with trends	0.116	0.0809	0.0897	0.0596	0.167**	0.166**	0.13*	0.0958	0.0834	0.105	0.068	0.0913
	KPSS without trends	0.314	0.114	0.132	0.339	0.58**	0.189	0.452*	0.244	0.253	0.474**	0.222	0.508**

Note: Price differences and price ratios are specified in equation (1) and equation (2) respectively. Numbers of observations of price differences and price ratio is 72. Abr.: abbreviation. S.D.: standard deviation. ADF tests denote augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1981). PP denotes Phillips-Perron tests (Phillips & Perron, 1988). KPSS denotes Kwiatkowski, Phillips, Schmidt, Shin (KPSS) tests (Kwiatkowski et al., 1992). Max lags in KPSS are chosen by Schwert criterion and are equal to 11 for all the variables. Autocovariances is weighted by Bartlett kernel. Null hypothesis for ADF tests: existence of unit roots. Null hypothesis for PP tests: existence of unit roots. Null hypothesis for KPSS tests: stationary.

Table 2 OLS estimates of trends and seasonality in grass-fed premiums measured as price difference, 2014-2019

	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
Trend	-0.131***	-0.032	0.001	0.004	0.026***	0.005	0.012***	0.064***	0.034***	0.033***	-0.008	-0.018***
	(-4.62)	(-1.03)	(0.10)	(0.31)	(4.84)	(0.66)	(3.87)	(5.11)	(3.66)	(4.94)	(-1.57)	(-5.02)
Feb	0.888	6.758**	1.370	2.921**	-0.004	0.175	-0.800**	-0.687	0.179	-0.013	0.338	0.355
	(0.31)	(2.18)	(1.10)	(2.40)	(-0.01)	(0.23)	(-2.27)	(-0.55)	(0.19)	(-0.02)	(0.67)	(0.98)
Mar	2.422	4.302	1.581	2.236*	0.133	1.087	-0.199	-0.913	0.851	-0.255	-0.176	0.756**
	(0.85)	(1.38)	(1.27)	(1.84)	(0.25)	(1.43)	(-0.56)	(-0.72)	(0.90)	(-0.39)	(-0.35)	(2.09)
Apr	3.983	2.845	1.113	1.731	0.057	-0.450	-0.344	-1.291	-0.135	-0.281	-0.003	0.276
	(1.40)	(0.92)	(0.90)	(1.42)	(0.10)	(-0.59)	(-0.97)	(-1.02)	(-0.14)	(-0.42)	(-0.01)	(0.76)
May	4.559	7.664**	1.937	1.436	0.637	1.168	0.124	-1.410	0.701	-0.963	-0.047	0.369
	(1.60)	(2.47)	(1.56)	(1.18)	(1.18)	(1.54)	(0.35)	(-1.12)	(0.74)	(-1.46)	(-0.09)	(1.02)
Jun	2.842	9.645***	1.275	0.980	0.113	1.263	-0.056	-0.956	1.058	-1.294*	0.318	0.267
	(1.00)	(3.10)	(1.03)	(0.80)	(0.21)	(1.66)	(-0.16)	(-0.76)	(1.12)	(-1.96)	(0.63)	(0.74)
Jul	4.311	2.740	1.657	2.279*	-0.483	0.178	-0.705*	-1.050	0.640	-0.945	-0.148	0.718*
	(1.51)	(0.88)	(1.33)	(1.87)	(-0.89)	(0.23)	(-1.99)	(-0.83)	(0.68)	(-1.43)	(-0.29)	(1.99)
Aug	4.458	3.219	2.063	1.753	-0.744	0.762	-0.730**	-0.167	-0.206	-1.463**	-0.057	0.509
	(1.56)	(1.03)	(1.66)	(1.44)	(-1.37)	(1.00)	(-2.06)	(-0.13)	(-0.22)	(-2.21)	(-0.11)	(1.41)
Sep	2.584	2.632	1.543	1.439	-0.252	-0.345	-0.292	-0.398	-0.355	-0.505	-0.031	0.171
	(0.91)	(0.84)	(1.24)	(1.18)	(-0.46)	(-0.45)	(-0.83)	(-0.31)	(-0.38)	(-0.76)	(-0.06)	(0.47)
Oct	2.255	4.591	1.905	1.672	0.457	0.523	-0.179	-1.007	-0.733	-0.586	-0.113	0.326
	(0.79)	(1.47)	(1.53)	(1.37)	(0.84)	(0.69)	(-0.51)	(-0.80)	(-0.77)	(-0.88)	(-0.22)	(0.90)
Nov	3.223	2.284	1.672	2.185*	0.031	0.982	-0.371	-1.226	-0.200	-0.840	-0.075	0.770**
	(1.13)	(0.73)	(1.34)	(1.79)	(0.06)	(1.29)	(-1.05)	(-0.97)	(-0.21)	(-1.27)	(-0.15)	(2.12)
Dec	9.722***	0.414	1.506	1.526	-0.152	-0.656	-0.465	0.370	-0.0913	-0.966	0.006	0.817**
	(3.40)	(0.13)	(1.21)	(1.25)	(-0.28)	(-0.86)	(-1.31)	(0.29)	(-0.10)	(-1.45)	(0.01)	(2.25)
Constant	22.938***	16.155***	9.028***	11.689***	4.394***	4.290***	4.328***	3.197***	6.726***	5.448***	4.758***	2.969***
	(10.45)	(6.74)	(9.43)	(12.45)	(10.52)	(7.33)	(15.89)	(3.29)	(9.24)	(10.68)	(12.31)	(10.66)
R2	0.366	0.255	0.066	0.121	0.362	0.229	0.338	0.350	0.250	0.361	0.080	0.373

Note: The dependent variables are price differences, specified in equation (1) .t-statistics in parentheses. * $p<0.10$, ** $p<0.05$, ***$p<0.01$. Trend: monthly trend. Begin with Jan 2014, and end in Dec 2019. R2: R-squared value. Standard errors are robust standard errors.

Table 3 Descriptive Statistics and Unit Root Tests for Dependent Variables

Descriptive Statistics												
Annual Difference of Price Difference												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
Mean	-1.054	0.231	0.184	0.224	0.320	0.017	0.171	0.685	0.257	0.301	0.023	-0.128
Median	-0.175	0.240	0.140	0.515	0.180	-0.040	0.245	0.510	0.175	0.450	0.095	-0.235
S.D.	6.61	7.51	3.23	3.37	1.34	1.80	0.88	3.18	2.39	1.67	1.27	0.87
Annual Difference of Price Ratio												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
Mean	-0.084	0.036	0.002	0.061	0.103	0.016	0.044	0.064	0.020	0.026	-0.004	-0.036
Median	-0.072	0.090	-0.049	0.059	0.098	0.032	0.056	0.030	0.025	0.046	0.011	-0.064
S.D.	0.87	1.44	0.84	0.49	0.45	0.73	0.28	0.96	0.48	0.26	0.27	0.19
Price Difference Ratio												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
Mean	-0.021	0.079	0.148	0.049	0.155	-0.168	0.076	0.470	0.070	0.108	0.049	-0.001
Median	-0.008	0.017	0.014	0.037	0.032	-0.015	0.050	0.130	0.024	0.092	0.023	-0.086
S.D.	0.265	0.381	0.924	0.268	0.615	1.634	0.315	1.444	0.299	0.353	0.285	0.327
Unit Root Tests												
Annual Difference of Price Difference												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
ADF test with 1 lag	-4.558***	-3.180***	-4.720***	-3.900***	-4.749***	-4.232***	-3.745***	-3.048***	-3.580***	-6.098***	-4.418***	-3.611***
ADF test with 4 lag	-2.280***	-2.515**	-3.478***	-2.459**	-2.433	-3.645***	-2.431**	-2.513**	-2.610**	-2.428**	-1.935*	-2.208**
ADF test with 8 lag	-1.320	-1.724*	-2.922***	-2.038**	-2.148	-1.624*	-2.207**	-2.555**	-2.477**	-1.706*	-3.209***	-1.720*
ADF test with 12 lag	-1.334	-1.787*	-4.479***	-3.522***	-2.194	-1.876*	-2.692***	-1.698*	-2.559**	-1.177	-2.635***	-2.495**
PP without trends	-4.937***	-5.239***	-5.115***	-6.721***	-5.580***	-5.855***	-4.772***	-4.879***	-6.670***	-6.625***	-4.082***	-4.561***
KPSS without trend	0.273	0.118	0.144	0.101	0.277	0.416*	0.254	0.0957	0.124	0.14	0.102	0.126
Annual Difference of Price Ratio												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
ADF test with 1 lag	-4.791***	-3.784***	-4.882***	-3.930***	-6.296***	-4.120***	-3.953***	-3.681***	-3.710***	-6.326***	-5.983***	-3.923***
ADF test with 4 lag	-1.892*	-2.727***	-2.698***	-2.372**	-2.553	-3.484***	-2.241**	-2.548**	-2.733***	-2.352**	-1.899*	-1.937*
ADF test with 8 lag	-1.906*	-2.041**	-2.012**	-2.143**	-2.131	-1.667*	-1.863*	-2.462**	-2.454**	-1.711*	-3.161***	-1.624*
ADF test with 12 lag	-1.712*	-2.217**	-4.657***	-3.744***	-1.500	2.065**	-1.927*	-2.170**	-2.400**	-1.503	-2.816***	-2.173**
PP without trends	-5.173***	-5.407***	-5.007***	-6.806***	-7.328***	-5.623***	-5.490***	-4.962***	-6.452***	-6.987***	-4.327***	-4.844***
KPSS without trend	0.138	0.0933	0.159	0.0632	0.407*	0.393*	0.216	0.0889	0.148	0.136	0.0892	0.119
Price Difference Ratio												
	Filet mignon	Tenderloin	Sirloin steak	Ribeye steak	Rump roast	Brisket	Chuck roast	Skirt Steak	Flat iron steak	Flank steak	Stew meat	Short ribs
ADF test with 1 lag	-4.777***	-3.719***	-17.494***	-4.005***	-5.161***	-5.872***	-4.540***	-3.646***	-3.349**	-5.939***	-3.621***	-3.822***
ADF test with 4 lag	-2.438**	-2.673***	-4.117***	-2.697***	-2.879*	-3.152***	-2.577	-2.321	-2.499	-2.458	-2.111**	-2.492**
ADF test with 8 lag	-1.416	-2.010**	-3.307***	-1.909*	-2.365	-2.395**	-2.333	-2.321	-2.763*	-1.793	-3.122***	-1.790*
ADF test with 12 lag	-1.491	-1.723*	-2.827***	-2.843***	-2.022	-1.979**	-2.495	-2.523	-3.215**	-1.881	-2.663***	-2.614**
PP without trends	-5.138***	-5.926***	-6.950***	-6.278***	-5.615***	-7.540***	-4.920***	-7.540***	-6.456***	-5.723***	-3.536***	-4.489***
KPSS without trend	0.291	0.132	0.285	0.0918	0.153	0.101	0.168	0.141	0.115	0.130	0.132	0.122

Note: S.D.: standard deviation. Numbers of observations are 60. ADF tests denote augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1981). PP denotes Phillips-Perron tests (Phillips & Perron, 1988). KPSS denotes Kwiatkowski, Phillips, Schmidt, Shin (KPSS) tests (Kwiatkowski et al., 1992). Price differences and price ratios are specified in equation (1) and equation (2) respectively. Annual Difference of price difference and price ratios are specified in equation (3) and (4) respectively. Price differences and price ratios are tested by ADF with trends. Student t tests in Table 1 have shown that except rump roast, other annual difference forms of price difference and price ratios are significantly equal to zero at the 95 confidence level. Therefore, we test annual difference of price differences as well as annual difference of price ratios using ADF tests without trends for all cuts other than rump roast. Rump roast is tested using ADF and PP without trends. Max lags in KPSS are chosen by Schwert criterion and are equal to 10 for all the variables. Autocovariances is weighted by Bartlett kernel. Null hypothesis for ADF tests: existence of unit roots. Null hypothesis for PP tests: existence of unit roots. Null hypothesis for KPSS tests: stationary.

TABLE 4. Descriptions of independent variables

VARIABLE	DESCRIPTIONS	UNIT	DATA SOURCE	LINK
Original Forms				
rINC	Real disposable personal income: Per Capita, Monthly, Seasonally Adjusted Annual Rate	Chained 2012 Dollars	U.S. Bureau of Economic Analysis, Real Disposable Personal Income: Per Capita [A229RX0], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/A229RX0, May 18, 2020.	https://fred.stlouisfed.org/series/A229RX0
FAFH sales	Nominal sales of FAFH foods	$ million	U.S. Department of agriculture, Economic Research Service. https://www.ers.usda.gov/data-products/food-expenditure-series/, May 19, 2020	https://www.ers.usda.gov/data-products/food-expenditure-series/
nINC	Nominal disposable personal income, Seasonally Adjusted Annual Rate	$ billion	U.S. Bureau of Economic Analysis, Disposable Personal Income [DSPI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DSPI, May 19, 2020.	https://fred.stlouisfed.org/series/DSPI
CLIM	The trends of published news in the U.S., with key words “climate change” or “greenhouse gas” or “global warming” AND “agriculture”	piece	Access World News from NewsBank	https://www.newsbank.com/
TAS	The trends of published news in the U.S., searched by key words “beef” and “taste”.	piece	Access World News from NewsBank	
PTN	The trends of published literature, searched by key words “zinc” or “iron” or “protein” and “beef”.	piece	PubMed	https://pubmed.ncbi.nlm.nih.gov/advanced/
FA	The trends of published literature, searched by key words “fat or cholesterol” or “heart disease or arteriosclerosis” and “diet” and “beef”.	piece	PubMed	
REV	Dummy to indicate the revocation of "grass-fed" lebal in January 2016 (0 for Dec 2015 and the months before, 1 for Jan 2016 and the months after)			

VARIABLE	DESCRIPTION	UNIT	CALCULATIONS
Annual Difference of Original Forms			
drINC_y	Annual difference of Real Disposable Personal Income: Per Capita, Monthly, Seasonally Adjusted Annual Rate	Chained 2012 Dollars	$drINC\_y = (rINC_t - rINC_{t-12})$
dFAFH_y	Annual difference of the share of disposable personal income spent on FAFH food in the United States.	%	$dFAFH\_y = (\frac{FAFH\ sales_t}{nINC_t} - \frac{FAFH\ sales_{t-12}}{nINC_{t-12}}) \times 100\%$
dCLIM_y	Annual difference of the trends of published news in the U.S., with key words “climate change” or “greenhouse gas” or “global warming” AND “agriculture”	piece	$dCLIM\_y = CLIM_t - CLIM_{t-12}$
dTAS_y	Annual difference of the trends of published news in the U.S., searched by key words “beef” and “taste”.	piece	$dTAS_y = TAS_t - TAS_{t-12}$
dPTN_y	Annual difference of the trends of published literature, searched by key words “zinc” or “iron” or “protein” and “beef”.	piece	$dPTN\_y = PTN_t - PTN_{t-12}$
dFA_y	Annual difference of the trends of published literature, searched by key words “fat or cholesterol” or “heart disease or arteriosclerosis” and “diet” and “beef”.	piece	$dFA\_y = FA_t - FA_{t-12}$
Annual Difference of Logarithm Forms			
dlogrINC_y	Annual difference of Logarithm Real Disposable Personal Income: Per Capita, monthly, Seasonally Adjusted Annual Rate	Chained 2012 Dollars	$dlogrINC\_y = \log rINC_t - \log rINC_{t-12}$
dFAFH_y	Annual difference of share of disposable personal income spent on FAFH food in the United States.	%	$dFAFH\_y = (\frac{FAFH\ sales_t}{nINC_t} - \frac{FAFH\ sales_{t-12}}{nINC_{t-12}}) \times 100\%$
dlogCLIM_y	Annual difference of the logarithm trends of published news in the U.S., with key words “climate change” or “greenhouse gas” or “global warming” AND “agriculture”	piece	$dlogCLIM\_y = \log CLIM_t - \log CLIM_{t-12}$
dlogTAS_y	Annual difference of the logarithm trends of published news in the U.S., searched by key words “beef” and “taste”.	piece	$dlogTAS\_y = \log TAS_t - \log TAS_{t-12}$
dlogPTN_y	Annual difference of the logarithm trends of published literature, searched by key words “zinc” or “iron” or “protein” and “beef”.	piece	$dlogPTN\_y = \log PTN_t - \log PTN_{t-12}$
dlogFA_y	Annual difference of the logarithm trends of published literature, searched by key words “fat or cholesterol” or “heart disease or arteriosclerosis” and “diet” and “beef”.	piece	$dlogFA\_y = \log FA_t - \log FA_{t-12}$

Note: Since dFAFH_y represents the ratio difference of food away from home on income, we don't need to take its logarithm form in Annual Differnce of Logarithm Forms. That's to say, dFAFH_y in Annual Difference of original Forms is the same as the one in Annual Differnce of Logarithm Forms.

Table 5. Descriptive statistics and Unit Root Tests for independent variables

Annual Difference of Original Forms						
	Income	FAFH	Climate	Taste	Protain	Fat
Abr.	drINC_y	dFAFH_y	dCLIM_y	dTAS_y	dPTN_y	dFA_y
Mean	1054.13	0.49	62.50	-59.63	1.00	-0.45
Median	1111.00	0.45	55.00	-45.50	2.00	-0.50
S.D.	423.136	0.772	215.811	101.570	6.886	4.196
ADF test with 1 lag	-1.732	-2.626*	-3.427**	-3.860***	-4.514***	-5.712***
ADF test with 4 lag	-1.765	-2.377	-1.418	-2.616*	-1.786*	-3.743***
ADF test with 8 lag	-3.163	-1.429	-1.319	-2.156	-2.414**	-2.240**
ADF test with 12 lag	-1.765	-1.236	-1.813	-3.163**	-2.403**	-3.346***
PP without trends	-1.964	-5.740***	-4.130***	-6.827***	-6.523***	-8.152***
KPSS without trend	0.126	0.511**	0.277	0.101	0.174	0.0971
Annual Difference of Logrithm Forms						
	Income	FAFH	Climate	Taste	Protain	Fat
Abr.	dlogrINC_y	dFAFH_y	dlogCLIM_y	dlogTAS_y	dlogPTN_y	dlogFA_y
Mean	0.025	0.49	0.084	-0.065	0.040	-0.067
Median	0.025	0.45	0.086	-0.046	0.079	-0.059
S.D.	0.010	0.77	0.334	0.106	0.283	0.681
ADF test with 1 lag	-1.909	-2.626*	-3.590***	-3.909***	-4.307***	-6.017***
ADF test with 4 lag	-1.856	-2.377	-1.669	-2.384	-1.679*	-4.249***
ADF test with 8 lag	-3.335**	-1.429	-1.556	-2.059	-2.583**	-1.979**
ADF test with 12 lag	-1.851	-1.236	-2.040	-3.073**	-2.464**	-2.643***
PP without trends	-2.141	-5.740***	-4.228***	-6.792***	-6.735***	-8.047***
KPSS without trend	0.109	0.511**	0.251	0.136	0.159	0.0835

Note: See Table 4 for descriptions for each independent variable. Abr.: abbreviation. S.D.: standard deviation. Numbers of observations are 60. ADF tests denote augmented Dickey-Fuller (ADF) tests (Dickey & Fuller, 1981). PP denote Phillips-Perron tests (Phillips & Perron, 1988). KPSS denotes Kwiatkowski, Phillips, Schmidt, Shin (KPSS) tests (Kwiatkowski et al., 1992).As it shown in Table 5, among independent variables, only sustainability, protain and fat are significantly equal to zero in both annual difference of original forms and logrithm forms. We use ADF and PP tests without constant terms. Other independent variables are tested without trends but with constant terms. Max lags in KPSS are chosen by Schwert criterion and are equal to 10 for all the variables. Autocovariances is weighted by Bartlett kernel. Null hypothesis for ADF tests: existence of unit roots. Null hypothesis for PP tests: existence of unit roots. Null hypothesis for KPSS tests: stationary.

Table 6 OLS estimates of independent variables in annual difference in price difference

		Filet mignon	Tenderloin	Sirloin steak	Rump roast	Brisket	Chuck roast	Skirt steak	Stew meat	Short ribs
(1)	Income	-0.0043	-0.0012	0.0024*	0.0012**	0.0007	0.0006	-0.0035**	0.0005	0.0004
		(-1.61)	(-0.41)	(1.92)	(2.13)	(0.92)	(1.53)	(-2.36)	(0.92)	(1.29)
(2)	FAFH	1.2194	0.4632	0.5712	0.1138	0.6364	0.0559	-0.0751	0.3112	0.2904
		(1.12)	(0.33)	(1.00)	(0.47)	(1.43)	(0.33)	(-0.14)	(1.41)	(1.45)
(3)	Climate Change	0.0081*	0.0115**	-0.0016	0.0015*	0.0037***	0.0013**	-0.0038**	0.0027***	0.0011*
		(1.79)	(2.32)	(-0.73)	(1.87)	(3.05)	(2.46)	(-2.13)	(3.53)	(1.97)
(4)	Taste	0.0007	0.0173*	0.0062	0.0013	0.0027	0.0015	0.0008	0.0020	0.0008
		(0.10)	(1.75)	(1.66)	(0.83)	(1.22)	(1.40)	(0.19)	(1.26)	(0.67)
(5)	Protein	0.0954	0.2937*	-0.0314	0.0288	0.0157	0.0155	0.0100	0.0458*	0.0172
		(0.90)	(1.81)	(-0.50)	(1.39)	(0.52)	(1.16)	(0.19)	(1.82)	(1.06)
(6)	Fat	0.0390	0.1124	-0.0595	0.0634*	-0.0793*	0.0110	-0.0213	0.0020	0.0004
		(0.25)	(0.43)	(-0.63)	(1.79)	(-1.93)	(0.43)	(-0.30)	(0.05)	(0.01)
(7)	Revocation	-5.5044*	-3.9734	-1.4680	0.6186	2.6336*	0.3726	-0.5896	-0.9484	-0.5773
		(-1.75)	(-0.83)	(-0.86)	(0.81)	(1.98)	(0.86)	(-0.25)	(-1.25)	(-0.91)
(8)	Trends	-0.0185	0.0236	0.0128	-0.0414**	-0.0763***	-0.0268**	0.0183	0.0043	0.0053
		(-0.26)	(0.28)	(0.35)	(-2.62)	(-3.25)	(-2.48)	(0.51)	(0.31)	(0.46)
(9)	Constant	7.2619*	3.7796	-1.3260	-0.2659	-0.9214	0.0682	4.5553*	-0.0738	-0.4476
		(1.80)	(0.75)	(-0.78)	(-0.30)	(-0.72)	(0.13)	(1.80)	(-0.10)	(-0.77)
(10)	R2	0.2511	0.2035	0.2946	0.2496	0.3484	0.2111	0.2323	0.4045	0.2850
(11)	Adjusted R2	0.1336	0.0786	0.1839	0.1319	0.2461	0.0873	0.1119	0.3111	0.1728
(12)	p value of F test	0.0066	0.0245	0.0334	0.0001	0.0017	0.0015	0.0058	0.0000	0.0082

Note: The dependent variables are annual difference of price differences , specified in equation (3). Independent variables are speficied in Table 4. See Table 4 for the descriptions for each independent variable. OLS estimates without meaningful specification are omitted given by p values of F test. The number of observations is 60 for each estimation. t-statistics in parentheses. Trend: monthly trend, starting with Jan 2015 and ending in Dec 2019. R2: R-squared value. Adj R2: Adjusted R-squared value. Standard errors are robust standard errors. *: p<0.10, **: p<0.05, ***:p<0.01.

Table 7 Beef cut panel estimates of independent variables in annual difference in price difference

		(1) OLS1	(2) OLS2	(3) FGLS1
(1)	Income	-0.0003	-0.0003	0.0001
		(-0.67)	(-0.70)	(0.42)
(2)	FAFH	0.4128*	0.4128*	0.2242*
		(1.79)	(1.87)	(1.81)
(3)	Climate Change	0.0020***	0.0020***	0.0017***
		(2.74)	(2.86)	(4.31)
(4)	Taste	0.0036**	0.0036**	0.0022***
		(2.42)	(2.52)	(2.77)
(5)	Protein	0.0408*	0.0408**	0.0273**
		(1.93)	(2.01)	(2.41)
(6)	Fat	0.0052	0.0052	0.0012
		(0.16)	(0.17)	(0.07)
(7)	Revocation	-0.4933	-0.4933	-0.3511
		(-0.71)	(-0.74)	(-0.94)
(8)	Trends	-0.0096	-0.0096	-0.0105
		(-0.65)	(-0.68)	(-1.32)
(9)	Constant	0.9446	0.9446	0.4768
		(1.25)	(1.30)	(1.18)
(10)	R2	0.0526	0.0398	

Note: The dependent variables are annual difference of price differences , specified in equation (3). Independent variables are speficied in Table 4. See Table 4 for the descriptions for each independent variable. OLS1: Pooled OLS with beef cut dummies. OLS2: Pooled OLS with panel-corrected standard errors. FGLS1: Pooled feasible GLS with a heteroskedastic error structure with cross-sectional correlation. The number of observations is 720. The number of groups is 12. t-statistics in parentheses. Trend: monthly trend, starting with Jan 2015 and ending in Dec 2019. R2: R-squared value. Standard errors are robust standard errors. *: p<0.10, **: p<0.05, ***:p<0.01.

Figure 1. Monthly Beef Prices ($/lb)

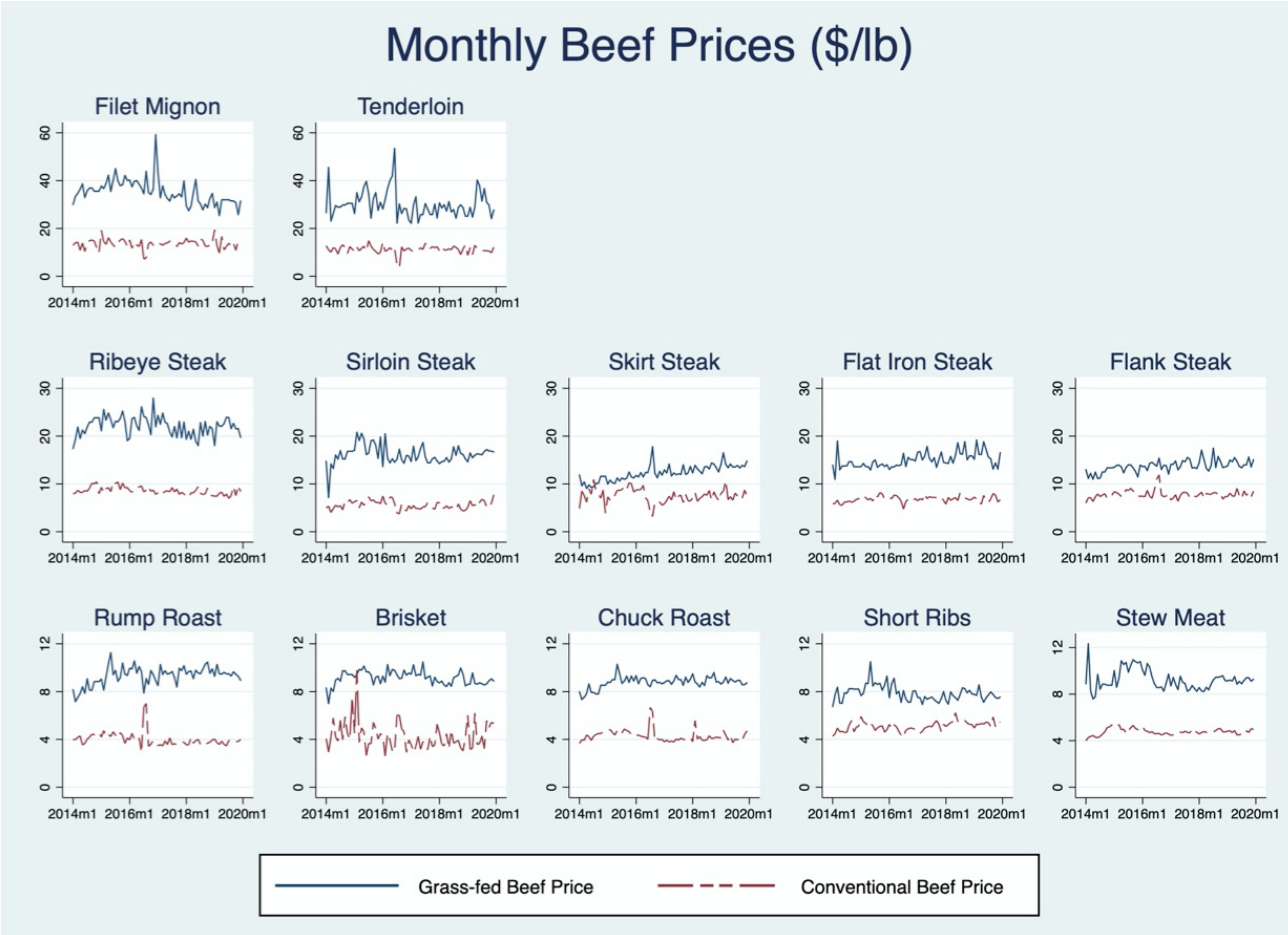

Figure 2. Beef Price Premium ($/lb)

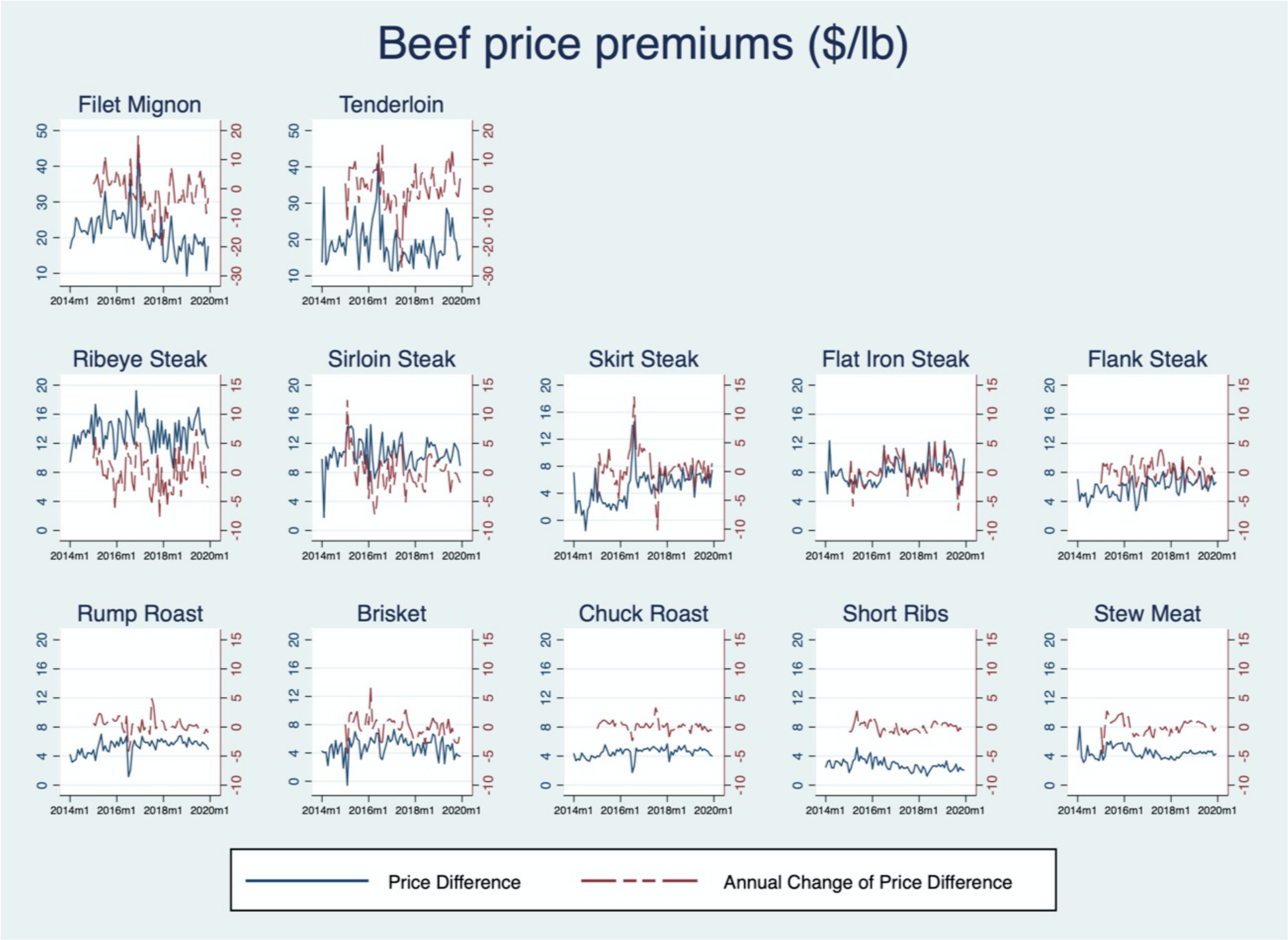

Table A. Beef individual estimates and cut panel estimates of independent variables in annual difference of price ratios

		Individual Cut								Cut Panel Estimates
		Tenderloin	Rump roast	Brisket	Chuck roast	Skirt steak	Flat iron steak	Stew meat	Short ribs	FGLS2
(1)	Income	-47.2186	5.3681	13.0675	2.0136	-44.4444**	-12.4807*	-1.5649	-0.5447	-4.3619*
		(-1.53)	(0.62)	(1.04)	(0.38)	(-2.21)	(-2.01)	(-0.33)	(-0.17)	(-1.67)
(2)	FAFH	-0.0030	-0.0093	0.2028	0.0317	-0.0587	0.0362	0.0729	0.0630	0.0434*
		(-0.02)	(-0.12)	(1.26)	(0.56)	(-0.43)	(0.46)	(1.51)	(1.42)	(1.66)
(3)	Climate Change	-0.0519	0.3610*	1.1256***	0.3250**	-0.7924**	-0.1874	0.4291***	0.1966***	0.1416**
		(-0.09)	(1.88)	(3.78)	(2.60)	(-2.07)	(-0.79)	(3.89)	(2.78)	(2.45)
(4)	Taste	1.7255	0.3376	0.9489	0.4886	0.2714	0.0686	0.4780	0.2995	0.4258***
		(0.87)	(0.66)	(1.23)	(1.44)	(0.23)	(0.12)	(1.51)	(1.28)	(2.74)
(5)	Protein	1.3371*	0.3085	0.1424	0.1678	0.2619	0.2094	0.2944**	0.1129	0.1559***
		(1.84)	(1.63)	(0.48)	(1.63)	(0.67)	(0.88)	(2.25)	(1.50)	(2.71)
(6)	Fat	-0.3468*	0.0964	-0.2652***	0.0214	-0.0763	-0.1215	-0.0210	0.0018	-0.0160
		(-1.94)	(1.14)	(-2.78)	(0.45)	(-0.70)	(-1.41)	(-0.41)	(0.05)	(-0.74)
(7)	Revocation	-1.3255	0.2326	1.0923**	0.2568*	-0.3933	0.2521	-0.1350	-0.1230	0.0553
		(-1.46)	(0.87)	(2.09)	(1.74)	(-0.55)	(1.12)	(-0.81)	(-0.85)	(0.57)
(8)	Trends	0.0173	-0.0130**	-0.0322***	-0.0086**	0.0057	0.0023	0.0017	0.0016	-0.0021
		(1.29)	(-2.54)	(-3.38)	(-2.64)	(0.57)	(0.40)	(0.57)	(0.65)	(-1.07)
(9)	Constant	1.7703	0.1714	-0.3539	0.0344	1.3945*	0.0410	0.0371	-0.0049	0.1284
		(1.50)	(0.52)	(-0.69)	(0.18)	(1.70)	(0.18)	(0.21)	(-0.03)	(1.19)
(10)	R2	0.1483	0.1589	0.3946	0.1867	0.2203	0.2363	0.3768	0.2570	
(11)	p value of F test	0.0259	0.0049	0.0004	0.0376	0.0370	0.0357	0.0004	0.0054	

Note: The dependent variables are annual difference of price ratios, specified in equation (4). Independent variables are speficied in Table 4. Individual cut shows the OLS estimates for each individual cut. OLS estimates without meaningful specification are omitted given by p values of F test. FGLS2: pooled feasible GLS estimates with a heteroskedastic error structure with cross-sectional correlation and AR1 autocorrelation structure. The number of observations for individual cut is 60 and for panel estimates is 720. The number of groups is 12 for panel estimates. t-statistics in parentheses. Trend: monthly trend, starting with Jan 2015 and ending in Dec 2019. R2: R-squared value. Standard errors are robust standard errors. See Table 4 for the descriptions for each independent variable. *: $p<0.10$, **: $p<0.05$, ***: $p<0.01$.

Table B. Beef individual estimates and cut panel estimates of independent variables in price difference ratio

		Individual Cut							Cut Panel Estimates
		Filet mignon	Tenderloin	Rump roast	Chuck roast	Skirt steak	Stew meat	Short ribs	FGLS2
(1)	Income	-6.5934	-1.7976	16.1835**	7.4732	-64.1758**	3.8859	6.5851	-1.6767
		(-1.49)	(-0.27)	(2.06)	(1.58)	(-2.22)	(0.84)	(1.24)	(-0.60)
(2)	FAFH	0.0505	0.0171	0.0157	-0.0028	-0.0709	0.0783	0.1204*	-0.0031
		(1.09)	(0.25)	(0.17)	(-0.06)	(-0.32)	(1.50)	(1.68)	(-0.11)
(3)	Climate Change	0.1985	0.2257	0.5194	0.3206**	-1.1174**	0.3976***	0.3309***	0.1564**
		(1.64)	(1.45)	(1.62)	(2.03)	(-2.02)	(4.09)	(2.77)	(2.55)
(4)	Taste	0.1397	1.2236**	0.2186	0.1990	0.7280	0.3437	0.4401	0.2260
		(0.41)	(2.22)	(0.44)	(0.71)	(0.37)	(1.13)	(1.04)	(1.37)
(5)	Protein	0.1099	0.4287**	0.2423	0.0915	0.5914	0.2602**	0.1986	0.1081*
		(0.99)	(2.13)	(1.60)	(1.04)	(0.80)	(2.39)	(1.20)	(1.78)
(6)	Fat	-0.0104	-0.1203*	0.1219	0.0410	0.0477	0.0100	0.0021	0.0272
		(-0.21)	(-1.74)	(1.34)	(0.84)	(0.24)	(0.22)	(0.03)	(1.19)
(7)	Revocation	-0.1987	-0.1719	0.4595	0.1649	-0.0645	-0.2843	-0.0940	-0.1358
		(-1.52)	(-0.80)	(1.29)	(0.93)	(-0.09)	(-1.64)	(-0.43)	(-1.33)
(8)	Trends	-0.0011	0.0025	-0.0160*	-0.0083*	-0.0075	0.0011	0.0006	-0.0016
		(-0.32)	(0.67)	(-1.76)	(-1.86)	(-0.73)	(0.38)	(0.16)	(-0.78)
(9)	Constant	0.2961*	0.2098	-0.1601	0.0002	2.4859**	0.0874	-0.1733	0.2585**
		(1.74)	(0.74)	(-0.63)	(0.00)	(2.22)	(0.48)	(-0.83)	(2.25)
(10)	R2	0.2358	0.2554	0.1236	0.1490	0.2927	0.4915	0.2547	
(11)	p value of F test	0.0045	0.0248	0.0020	0.0103	0.0354	0.0000	0.0056	

Note: The dependent variables are annual difference of price difference ratio, specified in equation (5) . Independent variables are speficied in Table 4. Individual cut shows the OLS estimates for each individual cut. OLS estimates without meaningful specification are omitted given by p values of F test. FGLS2: pooled feasible GLS estimates with a heteroskedastic error structure with cross-sectional correlation and AR1 autocorrelation structure. The number of observations for individual cut is 60 and for panel estimates is 720. The number of groups is 12 for panel estimates. t-statistics in parentheses. Trend: monthly trend, starting with Jan 2015 and ending in Dec 2019. R2: R-squared value. Standard errors are robust standard errors. See Table 4 for the descriptions for each independent variable. *: p<0.10, **: p<0.05, ***: p<0.01.