Title
Economics of Food Attributes Linked to Farm Practices

Author
Lee, Hanbin

Publication Date
2022

Peer reviewed|Thesis/dissertation

Economics of Food Attributes Linked to Farm Practices

By

HANBIN LEE
DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Agricultural and Resource Economics

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

Approved:

____

Daniel A. Sumner, Chair

____

Richard J. Sexton

____

Kevin Novan

Committee in Charge

2022

Abstract

This dissertation explores the economics of food attributes linked to production practices. I consider two distinct farm commodities: pork and carrots. The pork study models and simulates the economic consequences of prospective retail regulations that restrict farm practices used to produce pork products sold within the regulated jurisdiction. The carrot study estimates econometrically retail demand parameters for carrot attributes linked to farm production and processing practices.

In the pork study, I analyze the controversial regulations on sales of pork products in California that were mandated by the voter-approved Proposition 12 (Prop 12). Prop 12 requires uncooked pork cuts sold in California must originate from hogs whose mother sows were housed as set forth in Prop 12 and accompanying regulations. As of August 2022, implementation of Prop 12 is on hold pending outcomes of state and federal legal challenges.

In this dissertation, I develop a detailed, empirical economic simulation model of the implications of Prop 12 for quantities and prices of hogs and pork. Simulation results show that, using a range of values for applicable parameters, compliant farrowing operations will incur about 4% higher costs, pork processors and marketers also incur added costs, and California retail prices of covered cuts of pork will rise by about 7%. California consumers of covered cuts of pork lose about $260 million annually. Hog producers who comply with Prop 12 standards in order to supply the California market will, on average, receive greater profits. Market impacts are minimal for hog producers who choose not to comply with Prop 12 standards and for prices and quantities of pork sold outside California.

The second part of this dissertation investigates consumer demand for carrot product attributes that are linked to two sets of production practices: organic farming and fresh-cut processing practices. The demand for food product attributes tied to production practices is an increasingly important feature of food markets and are related to claims about health and nutrition, convenience, and sustainability broadly. Carrots are a low-cost staple vegetable in the American diet, but little economic research has been devoted to carrot demand or specifically to demand for organic and fresh-cut attributes. For data, I conducted seven waves of large web-based surveys over a period of more than 15 months, before and during the COVID 19 pandemic. My sample includes hundreds of thousands of responses to simple questions about willingness to pay (WTP) for carrots. This empirical approach was feasible because the surveys were conducted with a low-cost online platform. One contribution of my research is to explore the efficacy of such an approach to estimating specific demand parameters.

The major empirical findings are that the median respondents who face two carrot packages systematically indicate a significant willingness to pay more for organic and fresh-cut products and the measured WTP differentials are broadly consistent with market evidence. Also, the share of consumers choosing the higher-priced alternative declines markedly with the price differential. Moreover, I found that WTP estimates are consistent over periods before and during the pandemic, which indicates stability in demand for carrot attributes even in the context of massive economic, supply chain, and social dislocation.

Acknowledgments

I appreciate my dissertation committee members for their valuable advice and guidance. I am especially grateful to my advisor, Dan Sumner, for improving my research, writing, and communication skills. He also provided constant support and genuine concern for me. I learned from him how fun economics is. Rich Sexton has also been a good mentor. He made important contributions to this dissertation and gave me invaluable advice on research and writing. Kevin Novan also provided valuable comments to my dissertation.

I have had the great fortune to work with Dan Sumner as a research assistant on several projects. While working as a research assistant, I have met many good friends and colleagues at California Agricultural Issues Lab. I would like to thank Jonathan Barker, Georgi Gabrielyan, Robin Goldstein, James Lapsley, William Mattews, Jeremy Murdock, Yolanda Pan, Olena Sambucci, Don Stewart, and Pablo Valdes-Donoso. I am also indebted to the staff of the Department of Agricultural and Resource Economics. In particular, I thank Christy Hansen for her administrative support and Laurie Warren for computer services.

I also benefited from having friends and colleagues in Davis. I would like to thank Ji-Yeon Cheon, Jaerim Choi, Miki Khanh Doan, Pierce Donovan, Matthew Gammans, Jarrett Hart, Andrew Hobbs, Mengxin Ji, Jae Wook Jung, Ben King, Shri Kiruba, Ethan Krohn, Hairu Lang, Hyunjung Lee, Sangwon Lee, Seungduck Lee, Seunghyun Lee, Sukjoon Lee, Xiaoman Luo, Joanna Mathias, Laura Meinzen-Dick, Aleksandr Michuda, Kevin Nakolan, Karen Ortiz-Becerra, Daniel Putman, Sam Raburn, Jess Rudder, Zachariah Rutledge, Louis Sears, Dakyung Seong, Scott Somerville, Marcos Martinez Sugastti, Tor Tolhurst, Edward Whitney, Yitian Xiao, and Sophie Xu. In particular, I would like to thank Jisang Yu for his help and support when I first came to the United States. I also would like to express my gratitude to Hyunok Lee for her genuine concern for my well-being. She also provided valuable comments to my dissertation work.

I am also grateful to people that I met at the Department of Agricultural Economics and Rural Development, Seoul National University. Professors at Seoul gave me great classes, many research opportunities, and constant support. It was also very fortunate to work with Oh Sang Kwon, my academic advisor in the master program at Seoul. Classmates and other colleagues at Seoul also provided valuable moments. All their help led me to the place I am today.

Last, but of course not least, I owe thanks to my parents, Unghyeon Lee and Gyeongnam Lee, and my brother, Jaehyeon Lee. I could not finish this dissertation without their love and support.

Contents

Abstract ii

Acknowledgments iv

List of Tables xi

List of Figures xvi

Chapter 1. Introduction and Overview 1

1.1. Background to the Research 1

1.2. Summary of Research 2

1.3. Contributions 6

Chapter 2. Regulations Limiting Farming Practices for Products Sold within Local Jurisdictions: Regulations and Research Background 9

2.1. Regulation Examples 9

2.1.1. Example 1. Bans on the Sale of Products from Farm Animals Confined in Small Cages 10

2.1.2. Example 2. Bans on the Sale of Foie Gras 13

2.1.3. Example 3. Bans on the Sale of Canned Tuna Caught with Drift Nets 15

2.2. Research Background: Mandates on Farming Practices, Mandatory/Voluntary Product Standards based on Farming Practices 16

2.3. Research Background: Farm Animal Treatment Regulations 18

2.4. Contributions 19

Chapter 3. Economic Framework for Regulations Limiting Farming Practices for Products Sold within Jurisdictions 23

3.1. Supply Chain Impacts of Subnational Regulations on Food Production 23

3.2. Economic Model 27

3.2.1. Baseline Model 28

3.2.2. Market in the Presence of Subnational Regulations 32

3.3. Conclusions 39

Appendix 3.A. Two Special Cases of the Constant Elasticity of Transformation Production Possibility Frontier 41

Appendix 3.B. Derivation of the Supply Functions of Hog Carcass Used for Covered and Non-Covered Pork 43

Appendix 3.C. Derivation of the Supply Function of Hog Carcass Used for Covered Pork as a Function of the Price of Live Hogs 45

Chapter 4. The Impact of California's 2022 Pork Rules on the North American Hog/Pork Supply Chain 49

4.1. Model Calibration 49

4.1.1. Calibration of the Primary Supply and Demand Functions 49

4.1.2. Calibration of the Derived Supply and Demand Functions 51

4.1.3. Costs of Compliance with Prop 12 51

4.1.4. Additional Costs of Processing and Marketing Prop 12-Compliant Pork 53

4.2. Simulated Impacts of Proposition 12 for Producers and Consumers 54

4.2.1. Baseline Scenario 54

4.2.2. Can Subnational Animal Welfare Regulations Increase Profits for All Producers? 57
4.3. Implications of Proposition 12 for Farm Treatment of Sows 61
4.3.1. Farm Treatment of Sows under Proposition 12 61
4.3.2. Policies Addressing the Farm Treatment of Hogs (Intended to Improve Animal Welfare) 61
4.4. Conclusions 64
Appendix 4.A. Robustness of Simulation Results by Different Specification of the Derived Supply and Demand Functions 66
Appendix 4.B. Derivation of Relations to Calibrate the Parameters of the CET Production Possibility Frontier 68
Appendix 4.C. Economic Effects of Proposition 12 Using Different Values of the Elasticity of Transformation 70
Appendix 4.D. Detailed Description of Parameter Specification 72
Appendix 4.E. Economic Effects of Proposition 12 When Some Farms Cannot Participate in the California Market due to Contractual Reasons 86

Chapter 5. Demand for Carrot Attributes Linked to Farm Production and Processing Practices: Research Background and Survey Data 91
5.1. Literature Review 92
5.1.1. Certified “Organic” Farm Practices as a Food Product Attribute 92
5.1.2. Fresh Cut as a Food Product Attribute 93
5.1.3. Demand Estimation with Survey Data 94
5.1.4. COVID-19 and Food Demand 96
5.2. The U.S. Carrot Industry: Organic Carrots and Fresh-Cut Carrots 97

5.3. An Overview of Survey Design 100

5.4. Descriptive Statistics on Demographics 104

5.5. Descriptive Statistics on Response Time 109

5.6. Summary of Findings and Implications for Model Specification.......................................111

Appendix 5.A. Demographics by the WTP Question Types 112

Appendix 5.B. Determinants of Response Time 116

Appendix 5.C. Descriptive Statistics on Demographics and Response Time by Periods 118

Appendix 5.D. Respondents with "I Don't Buy Carrots"...126

Chapter 6. Estimation of the Parameters of Demand for Food Attributes Linked to Production Practices: Using Multiple-Choice Questions 137

6.1. Eliciting Method 137

6.2. The Willingness to Pay Question...138

6.3. Descriptive Statistics..141

6.4. Econometric Strategy 150

6.5. Estimation Results 152

6.6. Summary of Findings...161

Appendix 6.A. Effects of Carrot Attributes and Other Variables on WTPs: Potential Effects of Outliers in the Response Time 163

Chapter 7. Estimation of the Parameters of Demand for Food Attributes Linked to Production Practices: Using Yes-No Questions 168

7.1. Willingness to Pay Question...168

7.2. Descriptive Statistics....172

7.3. Econometric Strategy....182

7.4. Estimation Results....185

7.4.1. Estimation Results of Utility Parameters in the Logit Regressions....186

7.4.2. Estimates of WTPs for Carrot Attributes by Carrot Pairs....196

7.4.3. Estimates of WTPs for Carrot Attributes by Demographic Attributes of Respondents....197

7.4.4. Estimates of WTPs for Carrot Attributes by Period....198

7.4.5. Projected Shares of Organic Carrots and Fresh-Cut Carrots by Price Premium....199

7.5. Summary of Findings in Chapters 2 to 4 and Implications....203

7.5.1. Summary of Findings....203

7.5.2. Implications for Economic Research....204

Appendix 7.A. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples by Four Different Pairs of Carrot Packages....207

Appendix 7.B. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples with Outliers in the Response Time....210

Chapter 8. Conclusions....216

List of Tables

4.1. Impacts of Proposition 12 on Hog and Pork Prices and Outputs, Producer Surplus, and Consumer Surplus..59

4.2. Impacts of Proposition 12 on Hog and Pork Prices and Outputs, and Producer Surplus When the California Uncooked Cut Demand Expands so that the Producer Surplus of Non-Compliers does not Decline with the Implementation of Prop 12 60

4.A.1. Simulated Market Outcomes under Proposition 12 by Different Specification of the Derived Supply and Demand Functions 67

4.C.1. Simulated Market Outcomes under Proposition 12 by Different Values of the Elasticity of Transformation..71

Table 4.D.1. Parameter Definitions, Base-Case Values, Specifications, and Sources 80

Table 4.D.2. Elasticities and the 2018 Market Data Used to Calibrate Parameters 81

Table 4.D.3. HS Codes, Covered and Non-Covered Pork, Canada, and the United States...........82

Table 4.D.4. Declarations from Farmers about Proposition 12 in the Appendices of National Pork Producers Council v. Ross, No. 20-55631 83

Table 4.E.1. Impacts of Proposition 12 When Some Farms Cannot Participate in the California Market due to Contractual Reasons 87

5.1. 2019 and 2020 U.S. Fresh Carrot Production, Imports, Exports, and Farm Price..................99

5.2. 2019 Average Carrot Retail Prices 99

5.3. Demographics for Subsamples Differentiated Selection of the Option, “I Don’t Buy Carrots.”..106

5.4. Demographics for Subsamples Differentiated Selection of the Option, “I Don’t Buy Carrots”, Excluding Respondents Whose Demographics are Not Inferred................................107

5.5. Descriptive Statistics on Response Time by the WTP Questions, the Choice of "I Don't Buy Carrots," and Whether Demographics are Inferred 110

5.A.1. Demographics by the WTP Question Types..113

5.A.2. Demographics by the WTP Question Types after Excluding Respondents Whose Demographics are Not Inferred 114

5.B.1. Determinants of Response Time: Linear Regression Results 117

5.C.1. Descriptive Statistics on Demographics, Choice of "I Don't Buy Carrots," and Response Time over Periods over Periods..120

5.C.2. Descriptive Statistics on Demographics, Choice of "I Don't Buy Carrots," and Response Time over Periods over Periods, Only Respondents Whose Demographics are Inferred 123

5.D.1. Determinants of the Choice of "I Don't Buy Carrots": Linear Regression Results 129

5.D.2. Determinants of the Choice of "I Don't Buy Carrots": Linear Regression Results, Period Dummies..130

6.1. Summary Statistics, Responses from Multiple-Choice Questions 145

6.2. Summary Statistics, Responses from Multiple-Choice Questions: A Subsample only with Demographics 147

6.3. Summary Statistics, Responses from Multiple-Choice Questions: A Subsample of Respondents in the Range from 5% to 95% in Response Time 148

6.4. Summary Statistics, Responses from Multiple-Choice Questions, Short WTP Intervals, by before and during COVID-19 149

6.5. Effects of Carrot Attributes and Other Variables on WTPs: Full Sample versus Sample Only with Respondents Whose Demographics are Inferred..157

6.6. Effects of Carrot Attributes and Other Variables on WTPs, with the Interactions between Carrot Attributes and Demographics 158

6.7. Effects of Carrot Attributes and Other Variables on WTPs, with the Interactions between Carrot Attributes and Periods....................159

6.8. Effects of Carrot Attributes and Other Variables on WTPs: Short WTP Intervals versus Long WTP Intervals 160

6.9. Median Willingness to Pay Estimates and Confidence Intervals 161

6.A.1. Summary Statistics, Responses from Multiple-Choice Questions, Long WTP Intervals, by before and during COVID-19 164

6.A.2. Effects of Carrot Attributes and Other Variables on WTPs: Potential Effects of Outliers in the Response Time....................165

7.1. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, Full Sample....................174

7.2. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, Full Sample....................175

7.3. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, Only Respondents with Demographics....................176

7.4. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, Only Respondents with Demographics....................177

7.5. Summary Statistics, Responses from Yes-No Questions, Non-Organic Full-Sized versus Organic Full-Sized, before and during COVID-19....................178

7.6. Summary Statistics, Responses from Yes-No Questions, Non-Organic Fresh-Cut versus Organic Fresh-Cut, before and during COVID-19 179

7.7. Summary Statistics, Responses from Yes-No Questions, Non-Organic Full-Sized versus Non-Organic Fresh-Cut, before and during COVID-19 180

7.8. Summary Statistics, Responses from Yes-No Questions, Organic Full-Sized versus Organic Fresh-Cut, before and during COVID-19 181

7.9. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Full Sample and Subsamples Including Only Respondents with Demographic Information 190

7.10. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Including Period Dummies 192

7.11. Marginal Effects on Probability of Choosing Organic Carrots versus Non-Organic Carrots or Baby Carrots versus Full-Sized Carrots 194

7.12. Median Willingness to Pay by Carrot Package Pairs...196

7.13. Median Willingness to Pay by Demographic Attributes of Respondents..........................198

7.14. Median WTP estimates for Carrot Attributes by Periods 199

7.15. Projected Shares of Organic Carrots and Fresh-Cut Carrots Given the Observed Average Retail Price Premium 202

7.16. Projected Shares of Organic Carrots and Fresh-Cut Carrots by Price Premium 202

7.A.1. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples by Four Different Pairs of Carrot Packages 208

7.B.1. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, A Subsample of Respondents in the Range from 5% to 95% in Response Time...........................211

7.B.2. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, A Subsample of Respondents in the Range from 5% to 95% in Response Time...........................212

7.B.3. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Full Sample and Different Subsamples with Outliers in the Response Time 213

List of Figures

3.1. Production Possibility Frontiers for Covered and Non-Covered Pork and Adjustment to a New Equilibrium in Response to a Relative Price Change 30

5.1. An Example of Surveys Distributed through Google Surveys 103

6.1. Multiple-Choice Questions as Included in Surveys 139

6.2. Accumulated Response Shares by WTP Thresholds 146

7.1. Yes-No Questions as Included in Surveys 170

Chapter 1. Introduction and Overview

This dissertation has two main parts that contribute to the economics of food attributes linked to production practices. The first part develops a simulation model to analyze the economics of California regulations that limit farming practices used for pork products sold within the state. The second study investigates econometrically consumer demand for food attributes using survey data on willingness to pay for carrots.

1.1. Background to the Research

Food companies have increasingly introduced products featuring farm practices as product attributes, with organic practices representing a leading example. About 1,400 new organic products (4.5% in total new U.S. food products) were introduced in 2009 and 3,000 (3.8% in total) in 2016 (USDA 2017).

To contribute to understanding the organic market, I explore econometrically buyer willingness to pay for carrots grown with organic practices relative to conventional carrots. I also export the demand for convenience and processing practices by exploring willingness to pay for fresh cut carrots relative to full sized carrots. Some food processing and marketing companies supply food products only from farm outputs produced with certain farm practices. For example, McDonalds and Walmart, have announced that within the next decade they will buy, use or sell only cage-free eggs (Strom 2015; Walmart 2016). As of May 8, 2016, over 160 prominent food companies had announced that they will use only cage-free eggs, most by 2025 (Lempert 2016). Although not generally practiced by major retailers, many specialty markets and restaurants offer only or primarily organic food products.

Governments also contribute to the demand shifts away from once conventional food products. For example, several U.S. states have introduced mandatory rules to eliminate conventional eggs from the in-state market. For example California and other states, including Massachusetts, Michigan, Oregon, and Washington, passed such laws(National Agricultural Law Center 2021; Oregon Department of Agriculture 2022) (CDFA 2022a; CDFA 2022b). California has implemented mandatory cage-free housing for eggs consumed in California starting January 2022 as a part of the implementation of Proposition 12 (CDFA 2022b).

My model of government restrictions on food products that may be sold based on farm practices, which is applied to California's Proposition 12 (Prop 12) rules for pork products, shows how specific features of regulations affect market outcomes. Such product regulations may be imposed only on buyers within a specific jurisdiction but apply to farm practices outside that jurisdiction. Such regulations seem to be increasingly common and controversial, as reflected by the Hog industry challenge of Prop 12 before the U.S. Supreme Court (CITE Here to case document). However, economists have not fully explored their impacts on prices and economic welfare, either within or beyond the regulating jurisdiction.

1.2. Summary of Research

The Prop 12 regulations on pork products allowed for sale in California specify mandates about how the breeding pigs are housed. The housing rules apply to sows that farrow pigs that produce pork to be sold to buyers in California. My model incorporates four empirical and regulatory features that determine economic impacts: (a) California comprises about 9% of the market for North American pork; (b) The regulations cover only some of the pork products from each hog. (c) When a fraction of production becomes California compliant, the converting farms incur conversion costs and higher ongoing production costs; (d) Segregation and traceability along the supply chain of hogs and pork destined for California is costly; and (e) The quantity demanded for covered and non-covered pork products respond to relative prices, which are affected by costs of production, and (f) pork demand may respond directly to the farm practice mandate.

My model projects the economic effects of Prop 12 on the North American hog/pork supply chain. It incorporates the vertical supply chain of representing farms, intermediaries, and consumers. The equilibrium is derived in the vertical market without regulations, which is then compared to the equilibrium after I incorporate the local jurisdiction limit on sale of pork products determined farm sow housing practices. The model includes two regions – inside and outside California – and three sets of agents along the supply chain – hogs farms, processors and marketers, and consumers in and outside California.

Quantitative simulations calibrated on recent market characteristics and response parameters from the literature show that: (1) compliant farrowing operations incur higher costs (by about 4%); (2) compliant processing and distribution operations incur higher costs (by about 5%); (3) covered pork products have higher retail prices in the regulated jurisdiction (by about 7%); (4) impacts on consumers outside the regulated jurisdiction and for the unregulated pork products are minimal, (5) with higher prices, California consumers of uncooked pork cuts (covered pork) have substantial welfare losses (about $260 million annual loss in consumer surplus), and (6) producer surplus impacts are small because consumers in the regulated jurisdiction pay higher prices that cover compliance costs. Results are robust to reasonable ranges of response parameters.

The major hog requirement of Prop 12 is that farrowing operations for which the meat from pigs is destined for California must provide group housing with more than the normal amount of space for sows. Operations that already use group housing have a compliance cost advantage over those that use stall housing. Although California demands pork from less than 10% of North American hogs and 30% of sows in North America are already in group housing, a sufficient share of pork products is available to be diverted to California under Prop 12. However, because the space per sow in the California-compliant group housing was higher than the North American standard, there remained significant costs of compliance at pig farrowing farms.

Prop 12 and, more broadly, regulations imposed at a local point of purchase are unlikely to be economically efficient ways to farm practices because they raise costs all along the supply chain as well as at the farm. To highlight the importance of this point, I evaluate an alternative policy under which California would directly subsidize farms to change their housing practices to meet Prop 12 housing standards. The analysis shows that, for the same cost to California residents, the alternative policy would cause more than twice as many sows to be housed in ways that meet California's standards than would under the Prop 12 regulations of California retail market standards.

To explore willingness to pay (WTP) for product attributes linked to two sets of carrot production practices, organic and fresh cut, I conducted a series of large on-line surveys of U.S. carrot buyers. Starting in December 2019, I asked on-line respondents about their willingness to pay for carrot packages of different attributes in 7 rounds of surveys over about 15 months until March 2021. In all more than 300,000 respondents provided data for my econometric estimation.

Respondents face one of two types of survey questions. The first type of question showed survey respondents a picture of a carrot package and asked which WTP interval represented the most they would be willing to pay for the displayed package. Alternative surveys displayed packages that differed by the organic attribute and the fresh cut attribute. My analysis compared WTP responses from groups that saw packages displaying different attributes.

In the other question framework, respondents were shown pictures of two packages side-by-side that differed by a single attribute (either organic or fresh cut), each with a stated price. Respondents were asked which of the two packages they would be willing to buy at the state price for each.

The results of this part of my dissertation are of two types: (a) substantiative about willingness to pay for carrot attributes, and (b) methodological about survey procedures.

Main substantiative empirical findings are: (a) Based on the questions for which respondents were shown side-by-side pictures of alternative packages, the median WTP for the organic attribute is estimated to be between \$0.19 to \$0.23 per pound (the baseline product price is \$1.00 per pound). (b) Based on the questions for which respondents were shown side-by-side pictures of alternative packages, the median WTP for the fresh cut attribute is estimated to be between \$0.47 to \$0.56 per pound (the baseline product price is \$1.00 per pound). (c) Willingness to pay results from the question when respondents faced a single picture of carrot package indicate a large response to price, suggesting that many respondents had a "baseline" market price for carrots in mind. However, this framework was less successful in eliciting differential willingness to pay for attributes in comparison with carrot packages that were not displayed. (d) Given the large sample sizes, parameters are precisely estimated, and differ little in response to large economic, supply chain, and social disruption over periods before and during the pandemic.

Overall, the research demonstrated that reasonable and useful willingness to pay information can be gathered from cost-effective surveys (\$0.10 per respondent). I documented stability of parameter estimates over time and found that showing respondents displays of relevant comparisons may be particularly important in framing the question.

1.3. Contributions

The first part of the dissertation, dealing with the California Prop 12 regulations of hog and pork regulations, makes three main contributions. The first contribution is to show how economic implications of consumer regulations that apply in a limited jurisdiction have implications for producers that depend on their cost of compliance, and for consumers that depend on whether they are within the jurisdiction of the product regulations.

The second contribution is to evaluate how such consumer product regulations that apply in local jurisdictions likely create incentives for only the producers already close to compliance to change their practices. This reduces the costs of the farm practice shifts, but also means that relatively little change occurs in farm practices.

The third contribution is to show that consumer product regulations tied to upstream production practices are especially costly ways to achieve changes in farm practices because they impose significant cost on processing and marketing services because of the need for segregation, certification, and traceability.

The second part of the dissertation, on consumer demand for carrot attributes, makes several broad contributions. First, although carrots are a widely consumed, staple vegetable in the American diet, very little economic research has been devoted to carrot demand broadly or on demand for organic and fresh cut attributes. My dissertation research begins to fill this lacuna. Second, I find that WTP parameter estimates were constant over periods of massive economic, supply chain, and social dislocation. Third, I show reliable and robust ways to elicit useful estimates from a large and cost-effective online survey. My sampling approach and my empirical procedures offer guidance to empirical research on consumer demand.

References

California Department of Food and Agriculture. 2022. (CDFA 2022a). *Meat, Poultry and Egg Safety Branch, Egg Safety and Quality Management Program, Shell Egg Food Safety, Section 1350*. Shell Egg Notice Documents. Available at: https://www.cdfa.ca.gov/ahfss/pdfs/regulations/ShellEggSection1350.pdf. Accessed May 2, 2022.

California Department of Food and Agriculture. 2022. (CDFA 2022b). *Animal Care Program*. Proposition 12, Farm Animal Confinement. Notice of Proposed Action. Available at: https://www.cdfa.ca.gov/ahfss/pdfs/regulations/AnimalConfinement1stNoticePropReg_05252021.pdf. Accessed May 2, 2022.

Lempert, P. 2016. "Shift to Cage-Free Eggs Is Likely to Disappoint." Forbes. May 8. Available at: https://www.forbes.com/sites/phillempert/2016/05/08/shift-to-cage-free-eggs-is-likely-to-disappoint/#118aaff55fd3. Accessed May 4, 2018.

National Agricultural Law Center. 2021. *States' Farm animal Confinement Statutes*. Available at: https://nationalaglawcenter.org/state-compilations/farm-animal-welfare/. Accessed May 2, 2022.

Office of the Attorney General. 2018. Department of Justice. State of California. Ballot Initiatives. Available at: https://oag.ca.gov/initiatives/active-measures. Accessed April 25, 2018.

Oregon Department of Agriculture. 2022. *About Senate Bills 805 & 1019*. Available at: https://www.oregon.gov/oda/programs/AnimalHealthFeedsLivestockID/Hens/Pages/AboutHens.aspx. Accessed May 2, 2022.

Strom, S. 2015. "McDonald's Plans a Shift to Eggs from Only Cage-Free Hens." The New York Times. September 9. Available at: https://www.nytimes.com/2015/09/10/business/mcdonalds-to-use-eggs-from-only-cage-free-hens.html. Accessed May 4, 2018.

U.S. Department of Agriculture, Economic Research Service. 2017. *New Products.* Available at: https://www.ers.usda.gov/topics/food-markets-prices/processing-marketing/new-products/.

Walmart. 2016. "Walmart U.S. Announces Transition to Cage-Free Egg Supply Chain by 2025." Available at: https://news.walmart.com/news-archive/2016/04/05/walmart-us-announces-transition-to-cage-free-egg-supply-chain-by-2025. Accessed August 18, 2022.

Chapter 2. Regulations Limiting Farming Practices for Products Sold within Local Jurisdictions: Regulations and Research Background

Chapters 2 to 4 examine the implications of California's Proposition 12 and more broadly regulations with two essential features: The first is that regulations restrict what people in a regulated jurisdiction can buy tied to farming practices.[1] Products covered by regulations cannot be sold unless those products are made from a farm raw material produced under certain restricted practices compared to conventional standard ones. The second feature is that the regulating jurisdiction is part of the (total) market under consideration before the regulations are implemented.

Chapter 2 provides regulation examples and research backgrounds. Chapter 3 develops an economic model to analyze the supply chain impacts of California's Proposition 12, as an example of this type of regulation. Chapter 4 uses the economic model to simulate and analyze the impacts of the California regulations.

Chapter 2 has four sections. Section 2.1 provides regulation examples. Section 2.2 provides the research background regarding regulations associated with farming practices. As noted earlier, the application in Chapter 4 is about farm animal treatment regulations, so Section 2.3 provides related background. Section 2.4 summarizes contributions.

2.1. Regulation Examples

[1] Although this chapter focuses on the contexts when farming practices are restricted by regulations, the analysis in this dissertation can be generalized to cases when regulations may restrict practices at any stage along a food supply chain, including production, processing, and marketing.

This section provides three examples: (i) bans on the sale of products from farm animals confined in small cages, (ii) bans on the sale of foie gras, and (iii) bans on the sale of canned tuna caught with drift nets.

2.1.1. Example 1. Bans on the Sale of Products from Farm Animals Confined in Small Cages

Many states, for example, Oregon, Colorado, Maine, Michigan, Florida, Arizona, and California, have passed some form of legislation controlling the housing conditions of several farm animals (for a review, see Schulz and Tonsor 2015). They control the housing practices of farms located within their jurisdictions. However, several states, including Arizona, Massachusetts, and California, enacted mandatory product standards on animal products sold within their jurisdictions based on whether certain housing practices are implemented in producing those products.

California: Bans on Selling Eggs based on Hen Housing

The first example is a series of regulations (Assembly Bill 1437 in 2010 and Proposition 12 of 2018) on selling egg products in California. Assembly Bill (AB) 1437 was approved in July 2010. This law prohibited selling shell eggs from egg-laying hens confined on a farm or place that was not in compliance with the housing standards of Proposition 2, another law enacted in 2008. According to the housing standards of Proposition 2, egg-laying hens must not be confined on a farm in a manner that prevents those hens from: (a) lying down, standing up, and fully extending his or her limbs, and (b) turning around freely (California Health and Safety Code (HSC) S. 25990). As indicated, the housing standards do not provide a specific measurement but instead specify the movement ability of egg-laying hens, which generated uncertainty regarding what housing would comply with the Prop 12 requirements. In May 2013, the California Department of Food and Agriculture specified the housing standards: a minimum of 116 square inches per hen must be allowed. AB 1437 was implemented in January 2015.

California voters passed another law, Proposition 12 (Prop 12), in 2018. Compared to 2008 Proposition 2, this law strengthened the animal housing requirements as follows: "confining a covered animal in a manner that prevents the animal from lying down, standing up, fully extending the animal's limbs, or turning around freely; … or after December 31, 2019, confining an egg-laying hen with less than 144 square inches of usable floor space per hen; or after December 31, 2021, confining an egg-laying hen with less than the amount of usable floor space per hen required by the 2017 edition of the United Egg Producers' Animal Husbandry Guidelines for U.S. Egg-Laying Flocks: Guidelines for Cage-Free Housing, or in an enclosure other than a cage-free housing system" (HSC S. 25991).

Like AB 1437, Prop 12 restricts selling shell egg products sold in California based on the housing requirements. However, unlike AB 1437, Prop 12 also covers liquid egg products. Also, unlike AB 1437, Prop 12 covers pork products and veal products based on the housing practices of breeding pigs and calves. Chapter 4 discusses the sow housing regulations of Prop 12.

Massachusetts: Question 3 on the November 8, 2016, Ballot and Senate Bill 2603

This law is known as the Massachusetts Minimum Size Requirements for Farm Animal Containment. It was Question 3 on the November 8, 2016, ballot in Massachusetts. More than 77% of Massachusetts voters supported this law to set housing requirements for covered animals, including egg-laying hens, breeding pigs, and calves raised for veal. Specifically, covered animals must not be confined to prevent a covered animal from lying down, standing up, fully extending the animal's limbs, or turning around freely, which is the same as the requirements in California's Proposition 2 in 2008. However, Question 3 provides a minimum space requirement for egg-laying hens: at least 1.5 square feet of usable floor space per hen, different from California's Proposition 2 in 2008. More importantly, Question 3 prohibits the sale of eggs, veal, or pork of a farm animal confined on a farm or a place that does not comply with the housing requirements. The space requirement of Question 3 in Massachusetts is stricter than that of AB 1437 and the intermediate phase (from January 2020 to December 2021) of Proposition 12 in California.

The proposed law in Massachusetts was scheduled to be implemented on January 1, 2022, when the ballot question was approved. However, before the implementation, on December 20, 2021, the Massachusetts General Court passed an amendment, Senate Bill 2603. The governor signed the bill on the following date, and it took effect on January 1, 2022.

The amendment makes the Massachusetts regulations comparable to California's (Prop 12) regarding egg-laying hens and egg products: (i) Now cages are not allowed. (ii) The housing requirements also cover hens raised for liquid eggs sold within Massachusetts. However, the amendment has not changed the housing requirements for breeding pigs and calves for veal.

Arizona: The Ballot on November 8, 2022

An initiative, the Arizona Farm Animal Confinement, was filed on January 11, 2021. If enough valid signatures are collected by July 2022, the initiative will be on the ballot in Arizona on November 8, 2022.

The initiative is to ban selling veal from calves, pork from breeding pigs, and eggs from hens when those animals are confined to areas below the following minimum space requirements: for calves, 43 square feet of usable floor space per calf; for breeding pigs, 24 square feet of usable floor space per pig; and for egg-laying hens, no use of cages, and 1.0 to 1.5 square feet of usable floor space per hen, depending on cage-free housing types. If the initiative is approved, the regulations will be implemented after May 1, 2023.

2.1.2. Example 2. Bans on the Sale of Foie Gras

Foie gras is a food product made of the liver of a duck or goose. Although foie gras can be produced using natural feeding, foie gras production is usually conducted by force-feeding. Force-feeding, often called gavage, is feeding a duck or goose with more food than they voluntarily eat, fatting the liver.[2] Animal rights activist groups, including the Humane Society of the United States, claim that force-feeding is inhumane treatment of animals (The Humane Society of the United States 2012).

Several countries attempted to prohibit force-feeding practices in production within their jurisdictions. For example, the Israeli Supreme Court ordered the Israeli Ministry of Agriculture to prohibit geese force-feeding to produce foie gras in 2003 (CHAI 2003). The United Kingdom banned foie gras production under the Animal Welfare Act 2006. However, these examples do not restrict selling foie gras products sold within the regulating jurisdiction. This subsection provides three examples of banning foie gras products sold within the regulating jurisdiction.

California: Senate Bill 1520

[2] The United States Court of Appeals for the Ninth Circuit described the force-feeding process: "the birds are force-fed in a process called gavage, during which feeders use a tube to deliver the feed to the crop sac at the base of the duck's esophagus" (http://cdn.ca9.uscourts.gov/datastore/opinions/2017/09/15/15-55192.pdf).

In 2004, California passed Senate Bill 1520, which changed the California Health and Safety Code. Section 25981 prohibits force-feeding in foie gras production: "a person may not force feed a bird for the purpose of enlarging the bird's liver beyond normal size" (HSC S. 25981). Section 25982 prohibits selling foie gras products in California: "a product may not be sold in California if it is the result of force feeding a bird for the purpose of enlarging the bird's liver beyond normal size" (HSC S. 25982).

Farms had a seven and one-half year period to modify their production practices. The regulations were implemented on July 1, 2012. To overturn the foie gras ban, in 2015, the California attorney general appealed to the Ninth Circuit. However, in 2017, the District Court favored the ban, and the law was upheld (Dolan, Harris, and Mohan 2017).

City of Chicago: An Ordinance Banning Foie Gras

In 2006, the Chicago City Council passed an ordinance banning foie gras, City Ordinance PO-05-1895. The ordinance prohibited selling foie gras in all food dispensing establishments in Chicago. Food dispensing establishments were defined as "any fixed location where food or drink is routinely prepared and served or provided for the public for consumption on or off the premises with or without charges."[3]

The ordinance became operative on August 22, 2006. Soon after the ordinance was passed, the city was sued by the Illinois Restaurant Association and a local Chicago restaurant in the state court, claiming that the ordinance violated the Illinois constitution. However, in 2007, the district court concluded that the ordinance did not violate the Illinois Constitution or the

[3] Mun. Code of the City of Chicago 4-8-010.

United States Constitution.[4] However, after lobbying by restaurant owners, in 2008, the Chicago City Council repealed the foie gras ban.

New York City: Banning the Sale or Provision of Certain Force-Fed Poultry Products

In November 2019, the mayor of New York City signed the bill banning the sale of force-fed poultry products. The New York City Council introduced the bill in January same year. After a series of hearings and amendments, the council approved the bill in October 2019. The bill is scheduled to take effect three years after it was enacted in November 2022.

The new law prohibits selling force-fed poultry products, stated as follows: "No retail food establishment or food service establishment, or agent thereof, shall store, keep, maintain, offer for sale, or sell any force-fed product or food containing a force-fed product." (The New York City Administration Code, Title 17, Chapter 19).[5] According to the definitions in the law, retail food establishment includes supermarkets, grocery stores, specialty food stores, and farmer's markets. Also, food service establishment includes any type of food service providers, stated as follows: "a place where food is provided for individual portion service directly to the consumer whether such food is provided free of charge or sold, and whether consumption occurs on or off the premises or is provided from a pushcart, stand or vehicle." (The New York City Administration Code, Title 17, Chapter 19).

2.1.3. Example 3. Bans on the Sale of Canned Tuna Caught with Drift Nets

[4] Illinois Restaurant Association v. City of Chicago. Available at: https://casetext.com/case/illinois-restaurant-association-v-city-of-chicago. Accessed January 9, 2022.
[5] https://codelibrary.amlegal.com/codes/newyorkcity/latest/NYCadmin/0-0-0-114006.

Traditionally, fishers have used dolphins to harvest tuna. Because mature tuna swim below dolphins, fishers use dolphins to locate tuna schools. Drift netting was a widely used fishing practice to harvest tuna. The nets are drawn around located tuna schools, and the bottom of the net is tightened. Then, the fish are trapped inside and hauled onboard. Because dolphins swim above the tuna schools, drift netting catches those dolphins, which frequently kills those dolphins.

In response to the reduced number of dolphins by drift netting, consumers boycotted canned tuna in the 1970s and 1980s (Parrish 1990). One type of consumer response was legislation. In Portland, Oregon, a group of consumers petitioned for an initiative to ban selling canned tuna caught by drift netting in 1990. However, their attempt did not result in legislation (Ramach 1996).

2.2. Research Background: Mandates on Farming Practices, Mandatory/Voluntary Product Standards based on Farming Practices

Subnational jurisdictions, e.g., U.S. states and municipalities, increasingly impose farming practices regulations within their jurisdictions (Sumner 2017). Examples include restrictions on farm organizational structure, regulation of farming practices that cause pollution, setting of minimum wages and working conditions for farm labor, and limiting the use of inputs such as chemicals and fertilizers in crop production and hormones and antibiotics in livestock production (Alwang, Wooddall-Gainey, and Johnson 1991; Sunding 1996; Metcalfe 2000; Schroeter, Azzam, and Aiken 2006; Zhang 2018). Although such regulations impact the cost of production and competitiveness of farms located within those jurisdictions, the products produced under these various regulatory regimes are eventually commingled in the supply chain without identity preservation and sold to consumers in integrated markets.

Such regulations differ significantly in their economic impact from an emerging body of laws and regulations that control production practices for food products sold within the regulating jurisdiction regardless of where the products were produced (Sumner 2017). A key example is California's Proposition 12 (Prop 12) that was approved by voters in November 2018 and set to be implemented fully in January 2022.[6] Prop 12 sets specific housing requirements for egg-laying hens, breeding pigs, and calves raised for veal and prohibits the sale in California of specified products derived from covered animals maintained in housing that does not meet these standards, regardless of where the covered animals were located. Other examples of such regulations are presented in the previous section.[7, 8]

Regulations such as Prop 12 also differ in their economic impacts from private standards imposed on farm production practices by downstream buyers such as grocery retailers and food-service operators. Such standards were studied by Saitone, Sexton, and Sumner (2015) and applied to restrictions on antibiotic use in pork production. The essential economics of private standards include the decision of downstream firms whether to impose such standards on their suppliers, and the decision of consumers whether to patronize sellers who adopt such standards or to avoid higher product costs by shopping elsewhere. These elements of seller and consumer

---

[6] As this dissertation is being finalized in the summer of 2022, Prop 12's implementation for pork has been delayed because of legal challenges, including a U.S. Supreme Court case pending for the 2022/23 term.

[7] Thus far, proposed federal legislation to prohibit states from imposing such regulations has been unsuccessful. One key example was the Protect Interstate Commerce Act proposed as part of the 2018 U.S. Farm Bill, but eventually excluded from the final bill (Vogeler 2020).

[8] Related examples also emerge in international trade when importing countries impose restrictions on agricultural products allowed to enter the country. The U.S. country of origin labeling of beef and pork, which was imposed in 2008 and removed in 2015, reduced imports of live animals by requiring specific labels on certain meat products (Sumner and Zuijdwijk 2019).

choice are not present when the regulation applies to all products of a particular type sold in the jurisdiction.

2.3. Research Background: Farm Animal Treatment Regulations

Consumers, activists, food companies, and governments regularly express broad farm animal welfare concerns and raise issues with specific farm animal treatment practices.[9] In response, companies have developed private standards for farm animal treatment that they publicize to avoid unwanted controversy or to attract consumers who, while still willing to consume animal products, may be willing to pay for alternative farm practices that they perceive as more accommodating to animal welfare.

More recently, there has been and increased government attention to farm animal treatment, beyond basic criminal sanctions on extreme cruelty. Such government regulation of farm practices may be applied to farms within a local jurisdiction or products consumed within the regulating judication, even when the production occurs outside that jurisdiction. Such regulations affect the cross-border movement of products and raise international issues well as controversy within national borders. Here in North America, subnational regulations raise important economic questions as well as controversy and challenges related to how they affect farms, consumers, and the supply chain outside the jurisdiction applying the regulations.

Regulations on farm animal treatment have received rather limited attention in the literature to date, with most prior studies focusing on California laws regarding housing for egg-laying hens (Matthews and Sumner, 2015). Mullally and Lusk (2018) and Carter, Schaefer, and

[9] Of course, some individuals and groups raise fundamental issues with the ethics of raising animals for food. A relatively small share of consumers rejects animal-based foods and other consumer products, and many companies supply the requirements of those consumers.

Scheitrum (2021) analyzed the impacts on egg prices and consumer welfare of AB 1437 that, beginning in 2015, banned egg products from hens confined in less than 116 square inches of space. Oh and Vukina (2021) simulated the impact of Prop 12 on the California shell egg market, finding an annual consumer welfare loss of about $72 million.

2.4. Contributions

I study California's sow housing regulations for pork products as an example of regulations of consumer products based on farming practices. My study differs from the previous work in several important aspects.

First, I study the Proposition's impacts on the hog and pork markets. Although many laws regulating farm animal treatment cover breeding pigs' housing, the impacts on the pig and pork supply chain have received little attention despite the importance of the industry.

Second, my analysis considers the case when a mandate only applies to a portion of the output of the live animal. Many products can generally be produced from a given farm animal, and laws regulating the sale of products into their jurisdiction based on the treatment of the farm animal must then specify which products from the animal are implicated. The prior studies of regulations on housing for egg-laying hens have largely been able to avoid this problem, but it is germane to most other animal-based products, including dairy, beef, pork, and poultry. Prop 12, for example, applies only to uncooked cuts of pork and does not restrict the sale of cooked pork products such as lunch meat and canned pork, including many hams, or products that are mixed or not "cuts of pork," such as sausages, ground pork, and pork hotdogs. It also excludes products containing pork mixed with other ingredients, such as pizza and soups.

Third, my model addresses regulatory compliance that entails the conversion of capital inputs to meet a standard's requirements and heterogeneity in farms' costs of compliance with a regulation. This issue is important generally and especially for regulations that pertain to farm animal housing. Farms in these settings will incur capital costs to achieve compliance and are usually heterogeneous with respect to the magnitude of these costs. This means that only the most efficient compliers will choose to meet a subnational standard. Although industry groups often oppose such regulations, I show that, as should be expected, heterogeneity in compliance costs means that the firms most efficient at meeting a regulatory standard will derive net benefits from its imposition.

Fourth, I incorporate segregation and traceability costs along food supply chains. In contrast to laws regulating farm production within the jurisdiction, laws regulating production practices for foods sold within a jurisdiction necessarily require preserving the identity of compliant products through the supply chain, making segregation of compliant and noncompliant products and traceability necessary. Although the general implications of traceability and segregation along food supply chains have been studied (Pouliot and Sumner 2008; Pendell et al. 2010; Sumner and Zuijdwijk 2019), their roles have received little attention in regulations of farm animal treatment.

References

Alwang, J., D. Wooddall-Gainey, and T. G. Johnson. 1991. "Farm Labor Legislation: A Compuer Program to Assist Growers." *American Journal of Agricultural Economics* 73(4): 1027-1035.

California Health and Safety Code. 2004. Division 20, Chapter 13.4, Section 25980-25984.

California Health and Safety Code. 2009. Division 20, Chapter 13.8, Section 25990-25991.

Carter, C. A., K. A. Schaefer, and D. Scheitrum. 2021. "Piecemeal Farm Regulation and the U.S. Commerce Clause." *American Journal of Agricultural Economics* 103(3): 1141-1163.

CHAI. 2003. *Verdict of the Supreme Court of Israel Foie Gras*. CHAI – Concern for Helping Animals in Israel. Available at: https://www.chai-online.org/en/compassion/foiegras/foiegras.pdf. Accessed January 9, 2022.

Dolan, M., J. Harris, and G. Mohan. 2017. "Chefs React Angrily as Federal Appeals Court Upholds California Ban on Foie Gras." The Los Angeles Times. September 15. Available at: https://www.latimes.com/local/lanow/la-me-ln-foie-gras-9th-circuit-20170915-story.html. Accessed January 10, 2022.

Matthews, W. A., and D. A. Sumner. 2015. "Effects of Housing System on the Costs of Commercial Egg Production." *Poultry Science* 94: 552-557.

Metcalfe, M. 2000. "State Legislation Regulating Animal Manure Management." *Applied Economic Perspectives and Policy* 22(2): 519-532.

Mullally, C., and J. L. Lusk. 2018. "The Impact of Farm Animal Housing Restrictions on Egg Prices, Consumer Welfare, and Production in California." *American Journal of Agricultural Economics* 100(3): 649-669.

New York City Administration Code. 2022. Title 17. Chapter 19.

Oh, S. E., and T. Vukina. 2021. "The Price of Cage-Free Eggs: Social Cost of Proposition 12 in California." *American Journal of Agricultural Economics*, Online Published, Available at: https://doi.org/10.1111/ajae.12279. Accessed July 28, 2022.

Parrish, M. 1990. "Film Turns Tide for Dolphins at StarKist Tuna: Environment: A Rock 'n' Roll Executive Carried the Public's Message: 'People Just Want to Let the Dolphin Alone.'" Los Angeles Times. April 14. Available at: https://www.latimes.com/archives/la-xpm-1990-04-14-fi-1067-story.html. Accessed January 9, 2022.

Pendell, D. L., G. W. Brester, T. C. Schroeder, K. C. Dhuyvetter, and G. T. Tonsor. 2010. "Animal Identification and Tracing in the United States." *American Journal of Agricultural Economics* 92(4): 927-940.

Pouliot, S., and D. A. Sumner. 2008. "Traceability, Liability, and Incentives for Food Safety and Quality." *American Journal of Agricultural Economics* 90(1): 15-27.

Ramach, J. 1996. "Dolphin-Safe Tuna Labeling: Are the Dolphins Finally Safe?" *Virginia Environmental Law Journal* 15(4): 743-784.

Saitone, T. L., R. J. Sexton, and D. A. Sumner. 2015. "What Happens When Food Marketers Require Restrictive Farming Practices?" *American Journal of Agricultural Economics* 97(4): 1021-1043.

Schroeter, J. R., A. M. Azzam, and J. D. Aiken. 2006. "Anti-Corporate Farming Laws and Industry Structure: The Case of Cattle Feeding." *American Journal of Agricultural Economics* 88(4): 1000-1014.

Schulz, L. L., and G. Tonsor. 2015. "The U.S. Gestation Stall Debate." *Choices* 30(1): 1-7.

Sumner, D. A. 2017. "Economics of US State and Local Regulation of Farm Practices, with Emphasis on Restrictions of Interstate Trade." *Annual Review of Resource Economics* 9: 13-31.

Sumner, D. A., and T. Zuijdwijk. 2019. "The Law and Economics of Canada's WTO Litigation Contesting U.S. Country-Of-Origin Labeling (COOL)." *Canadian Journal of Agricultural Economics* 67: 327-347.

Sunding, D. L. 1996. "Measuring the Marginal Cost of Nonuniform Environmental Regulations." *American Journal of Agricultural Economics* 78(4): 1098-1107.

The Humane Society of the United States. 2012. *An HSUS Report: The Welfare of Animals in the Foie Gras Industry.* Available at: https://www.humanesociety.org/sites/default/files/docs/hsus-report-welfare-foie-gras-industry.pdf. Accessed January 9, 2022.

Vogeler, C.S. 2020. "Politicizing Farm Animal Welfare: A Comparative Study of Policy Change in the United States of America." *Journal of Comparative Policy Analysis: Research and Practice*, DOI: 10.1080/13876988.2020.1742069

Zhang, W. 2018. "Costs of a Practice-Based Air Quality Regulation: Dairy Farms in the San Joaquin Valley." *American Journal of Agricultural Economics* 100(3): 762-785.

Chapter 3. Economic Framework for Regulations Limiting Farming Practices for Products Sold within Jurisdictions

This chapter develops an economic model to analyze the economic implications of restrictions on farming practices for products sold within a local jurisdiction. This chapter uses the contexts of California's Proposition 12 and the North American hog/pork supply chain, but the analysis can be applied more generally to local product regulations based on farming practices. Section 3.1 describes how subnational regulations of production practices for products sold in their jurisdictions impact costs along the supply chain. Section 3.2 uses this knowledge to set forth an economic model to study such regulations formally. Section 3.3 concludes.

3.1. Supply Chain Impacts of Subnational Regulations on Food Production

The impacts of Prop 12 and related subnational regulations depend importantly on the cost increases they impose at different stages of the supply chain. Most such regulations to date apply to animal housing. Compliant firms will incur fixed costs of adopting housing to a regulation's requirements, as well as additional variable costs for labor, feed, and veterinary services associated with deviating from conventional practices. Farms considering conversion must, thus, forecast whether a discounted incremental revenue stream from serving the regulating jurisdiction will be sufficient to cover the upfront and recurrent costs of the regulation.

Prop 12 mandates that breeding sows be afforded at least 24 square feet of usable floor space and not be confined to stalls apart from short periods associated with farrowing and nursing. My analysis indicates that about 30% of breeding pigs were already confined in group housing at the time of its enactment, albeit housing that did not meet the Prop 12 standards. Most of these farms would be able to convert to Prop 12 compliance at lower costs than operations using stall housing. The marginal converting operation will just break even (on expectation) from doing so, while inframarginal converters will earn incremental profits from converting.

As noted, regulations that restrict finished products that can be sold within the jurisdiction imply adjustments throughout the supply chain. Such regulations require segregation and traceability of products from compliant farms and compliant finished products throughout the supply chain, including creating new stock keeping units (SKUs) (Informa Economics 2010; Sumner and Zuijdwijk 2019). Hog production involves three main stages: farrowing, nursery, and finishing, which may or may not be vertically integrated. Prop 12 applies directly at the farrowing stage, where breeding pigs produce piglets and feed them for about 21 days. Prop-12 compliant hogs, those that are born and weaned at farrow operations that comply with Prop 12 regulations, receive no special treatment at the nursery and finished stages, but their identities must be preserved. Independent nursery and finishing operations must pay a higher price for pigs from Prop-12 compliant farrowing operations to cover the additional costs and to account for the higher value of some of the pork derived when the hogs are slaughtered. Operations further down the supply chain have no incentive to acquire these hogs unless they intend to preserve their identities and sell them into the segment of the supply chain producing pork products for California.

Primary processors slaughter hogs and produce uncooked cuts of pork and ground pork products. These products are sold to wholesalers, retailers, and foodservice providers, or secondary processors. Compliant hogs and pork products must be segregated from non-compliant ones at any stage of processing and marketing. Operations that sell to retailers will have to create new stock-keeping units (SKUs) for compliant products, imposing another one-time cost at this stage in the supply chain. Operations may also need larger warehouse space or extra facilities and equipment to stock and distribute compliant products separately from non-compliant ones.

Importantly, an alternative strategy for primary processors would be to require all the hogs entering a specialized processing facility to be California compliant. This strategy avoids the aforementioned segregation costs at the plant level. However, unless all the covered pork products from the plant were channeled to the California market, this strategy raises processor costs in terms of having to pay farms to produce and supply compliant hogs even when their meat will not be sold in California. Indeed, this is the argument made by Petitioners in the case challenging the Constitutionality of Prop 12 before the U.S. Supreme Court (*National Pork Producers Council v. Ross*, No. 21-468). I argue this cannot be a viable competitive strategy. A decision by some processors to comply with Prop 12 in their entire operations creates an opportunity for competing processors to not comply, and, therefore, to avoid paying higher costs for compliant hogs, and being able to produce and sell pork for the rest of the country more cheaply than a compliant processor. Thus, compliant processors would not be able to compete on price for sales to the rest of the country relative to non-compliant processors, which destroys the economic viability of the strategy.[1]

California's food retailers and food-service operators are, of course, also impacted by Prop 12. Indeed, the Proposition is directed toward these businesses. They are required under

[1] Multi-plant processors could consider having a plant dedicated to production of Prop 12 compliant product, which would also reduce incremental costs at the plant level. The problem with this strategy is sourcing enough compliant hogs within the plant's procurement area. As noted, farmers that can comply most cheaply are those already using group housing. A dedicated "Prop 12 plant" would incur higher raw product costs due to having to incentivize less efficient converters within its normal procurement area or expanding its procurement area to find efficient converters and then incurring higher shipment costs. With less than 10 percent of North American pork destined for California, relatively few farms would supply such pork.

California regulations to procure covered product only from suppliers that certify that the pork has been produced to meet the mandate of Prop 12.[2]

As noted, most farm products can serve as inputs into multiple finished products. For example, the livestock products at issue with most animal housing regulations may be sold to consumers in either cooked or uncooked formats and may be mixed with other products in sausages, soups, prepackaged dinners, etc. Higher costs associated with complying with the regulation can be recovered only on the subset of products covered under the regulation. Products coming from compliant farm product but not covered under the law can receive no price premium because they compete with the same products from noncompliant farming operations.

Coverage of finished products is a challenge for subnational regulating authorities because the wider the set of final products included under the regulation the greater will be the challenge to compliance and enforcement and the more economic actors that will be involved. Prop 12 provides an excellent example. It specifies regulated pork products as "whole pork meat," defined to mean "any uncooked cut of pork (including bacon, ham, chop, ribs, riblet, loin, shank, leg, roast, brisket, steak, sirloin or cutlet) that is comprised entirely of pork meat, except for seasoning, curing agents, coloring, flavoring, preservatives and similar meat additives" (California Health and Safety Code (HSC) S. 25991). The uncooked pure pork products subject to Prop 12 regulation comprise about 60% to 65% of the meat from a hog. Secondary processors that procure uncooked pork and other products from primary pork processors and utilize them to

[2] The specific language of Prop 12 concerning California food operators is the following: "A business owner or operator shall not knowingly engage in the sale within the State of California of any whole pork meat that the business owner or operator knows or should know is the meat of a covered animal who was confined in a cruel manner, or is the meat of immediate offspring of a covered animal who was confined in a cruel manner" (HSC S. 25990).

make ground products, sausages, cooked hams, lunchmeats, soups, etc. are not subject to Prop 12's regulations.[3]

The fact that only a subset of finished products that use the farm product input will be subject to the regulation raises interesting and unique economic issues that my model addresses. First, it creates an opportunity for consumers to avoid regulation-induced price increases by substituting non-covered products in place of those subject to the regulation. Second, it gives processors incentive and possible opportunity to adapt to a regulation by adjusting the share of covered and non-covered products produced from a given farm animal. In particular, compliant operations will have incentive to increase the share of covered product derived from an animal because non-covered products can capture no price premium.

3.2. Economic Model

I begin by modeling a perfectly competitive North American pork supply chain in the absence of regulation to establish a baseline model.[4] I then extend the model to incorporate the impacts of Prop 12. I categorize supply-chain participants into three groups: (i) farms that produce a raw-product input, (ii) intermediaries that convert the farm product into finished products and supply those products to consumers, and (iii) consumers who buy those products at retail through grocery stores or food-service establishments. For simplicity, I classify pork products into two composite categories: covered products and non-covered products. If one was concerned with

---

[3] An extreme example related to pork that illustrates the imperative for subnational regulations to specify product coverage is gelatin, which is derived from pig body parts and may be used in the production of an exceptionally wide range of products including wines, sugar coating on breakfast cereals, yogurt, baked goods, fruit gum, and juices.

[4] Although imperfect competition in meat supply chains has been a topical issue, empirical estimates of processor market power in red-meat industries have generally revealed at most only mild distortions from competitive behavior (Wohlgenant 2013, Sexton and Xia 2018), making perfect competition a reasonable simplifying assumption. The model could be extended to allow intermediary oligopoly and/or oligopsony power at the complexity cost of introducing multiple market-power parameters.

other marketable output from hog carcasses those might be a second category of non-covered products that likely would not substitute for covered pork.

3.2.1. Baseline Model

Primary supply of farm product: To maintain tractability with a relatively small number of parameters, a linear (inverse) market supply function is used for the farm product:[5]

$$P_f^S = a + bQ_f^S, \tag{3.1}$$

where a subscript f represents farms, P denotes price, and Q is quantity, a superscript S denotes a supply relationship, so Q_f^S denotes the quantity of farm raw material supplied.

Primary demand for final products: The inverse final demand for covered and non-covered products are specified in a linear form:

$$P_{r,C}^D = \gamma - \beta_{cc} Q_{r,C}^D - \beta_{cn} Q_{r,N}^D, \tag{3.2}$$

$$P_{r,N}^D = \theta - \eta_{nn} Q_{r,N}^D - \eta_{nc} Q_{r,C}^D, \tag{3.3}$$

where subscript r represents final demand (retail plus food service), subscripts C and N denote covered and non-covered products respectively, and superscript D denotes a demand relationship. P_r is the final product price, and Q_r is the quantity sold at retail and food service. Substitution by consumers between covered and non-covered products can occur based upon the cross-price coefficients, β_{cn} and η_{nc}.

Processing and marketing sector: The model specifies homogeneous intermediaries who acquire the farm product and convert it into final products sold downstream to consumers either at retail or food-service establishments. A representative processor produces two retail products,

[5] Although the conceptual model could be specified with more general functional forms, specific functions are needed to implement the simulation model that is essential to this research, so I develop the model directly in a format conducive to conducting simulations.

C and N, using two inputs, the finished hogs, q_f, and the composite of other inputs, k, where lower case q denotes firm-level values. No substitution is allowed between hogs and other inputs in production of cuts of pork and other pork products.[6] Constant returns to scale are assumed for production and marketing of both types of pork products.[7] Costs associated with the use of other inputs, k, in processing and marketing are $c_C q_{r,C}$ and $c_N q_{r,N}$, where c_C (c_N) is the constant per-unit processing cost for covered (non-covered) pork.

The finished hogs are transformed into the two outputs under variable proportions because specific parts of a hog carcass are more suitable for one type of pork product than another. For example, bacon and pork chops cannot be made from parts that would otherwise make sausage. The transformation is represented by a constant elasticity of transformation (CET) production possibility frontier (Powell and Gruen 1968):

$$q_f = A\left(\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}, \tag{3.4}$$

where $A > 0$ is a scale parameter, $0 < \alpha < 1$ is a share parameter, and $1 < \rho < \infty$ is a parameter that determines the elasticity of transformation $\tau = 1/(\rho - 1)$. For example, the CET production possibility frontier approaches fixed proportions as $\rho \to \infty$ (which implies $\tau \to 0$), i.e., no substitution in production between covered and non-covered products and approaches perfect transformation ($\tau \to \infty$) as $\rho \to 1$, i.e., perfect substitutability in production between covered and non-covered products.[8]

---

[6] Some prior studies (Wohlgenant 1989, 1993; Pendell et al. 2010) consider potential substitution between farm products and other inputs in production. However, because of the limited substitution of other inputs such as labor for hog carcass to produce pork products, for simplification, the model assumes no substitution. Rickard and Sumner (2008) allow substitution of other inputs for tomatoes in making tomato products with relatively small impacts on results.
[7] Constant returns in processing technology is a common simplifying assumption in studies of food supply chains (e.g., Wohlgenant 1989; Tomek and Kaiser 2014; Saitone, Sexton, and Sumner 2015).
[8] See Appendix 3.A for the derivation of these two special cases.

Figure 3.1 illustrates the production technology for three different values of τ: 0.2, 0.5, and 1.0. (I use distinctly different values of τ for clarity of the illustration in Figure 6.1, even though these differences are likely far outside a realistic range.) Each frontier passes the same baseline quantity point (point A). Each point on each frontier represents combinations of the maximum quantities of covered pork and non-covered pork that can be produced for a given quantity of finished hogs. The tradeoff between covered and non-covered products increases as the elasticity of transformation increases.

Figure 3.1 also illustrates optimal production combinations given different prices net of processing costs for covered and non-covered products. Given initial prices (superscript 0), equilibrium is at point A. Superscript 1 denotes higher net prices for covered products relative to non-covered products. The new equilibrium is at point C when $\tau = 0.5$ and point B when $\tau = 1.0$. More of the finished hog input is used to produce covered pork when $\tau = 1.0$.

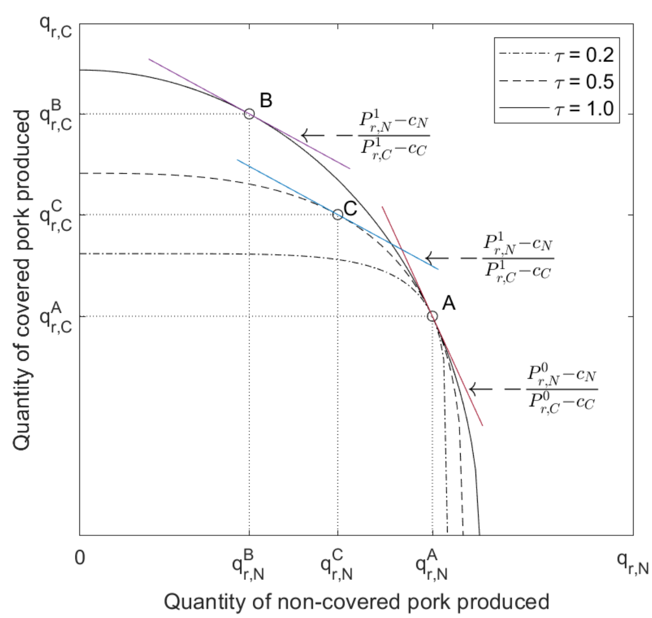


Figure 3.1. Production Possibility Frontiers for Covered and Non-Covered Pork and Adjustment to a New Equilibrium in Response to a Relative Price Change

Notes: The figure depicts alternative production possibility frontiers for intermediaries using the farm product to produce covered and non-covered products. The term τ represents the elasticity of transformation. Each line tangent to points A, B, or C depicts an isorevenue line. The superscripts 0 and 1 indicate two different periods with different prices.

With constant returns to scale and constant prices, the choice of the total output and number of hogs processed and marketed by a firm is not determinant unless additional constraints are imposed on the problem, such as a binding plant-capacity constraint. I consider the realistic setting whereby the representative processor has secured an ex ante contract commitment to procure q_f hogs, an amount I assume represents the efficient processing capacity. The processor's short-run decision then is the choice of covered and non-covered outputs to produce, given the live animal input q_f:

$$\max_{q_{r,C},q_{r,N}} \left(P_{r,C} - c_C\right)q_{r,C} + \left(P_{r,N} - c_N\right)q_{r,N}$$
$$\text{subject to } q_f = A\left(\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}. \tag{3.5}$$

Solving the first-order conditions and aggregating across intermediaries,[9] I obtain the supply functions of the two retail products conditional on the live hog quantity (see Appendix 3.B for derivation):

$$Q_{r,C}^S = \frac{Q_f^S}{A}\left(\alpha + (1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}^S - c_N}{P_{r,C}^S - c_C}\right)^{\tau+1}\right)^{-\frac{\tau}{\tau+1}}, \tag{3.6}$$

$$Q_{r,N}^S = \frac{Q_f^S}{A}\left((1-\alpha) + \alpha\left(\frac{1-\alpha}{\alpha}\frac{P_{r,C}^S - c_C}{P_{r,N}^S - c_N}\right)^{\tau+1}\right)^{-\frac{\tau}{\tau+1}}. \tag{3.7}$$

For both supply functions, as expected, the quantity supplied rises as the own price rises, while it falls as the cross price rises because $\tau > 0$ and $0 < \alpha < 1$. Equations (3.6) and (3.7) can be re-expressed as follows (see Appendix 3.C for derivation):

$$Q_{r,C}^S = Q_f^S\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,C}^S - c_C}{\alpha P_f^S}\right)^{\tau}. \tag{3.8}$$

[9] The second order condition is satisfied under $1 < \rho < \infty$ or $0 < \tau < \infty$, which guarantees a unique interior solution. In the fixed proportions case where $\tau = 0$, this economic solution is trivial at the fixed ratio.

$$Q_{r,N}^{S} = Q_f^S \left(\frac{1}{A}\right)^{1+\tau} \left(\frac{P_{r,N}^{S} - c_N}{(1-\alpha)P_f^S}\right)^{\tau}. \tag{3.9}$$

Equations (3.8) and (3.9) are helpful to understand the effect of incremental farm costs of hogs caused by the regulations, which will be introduced below. Using the CET relation expressed in equation 3.4, I obtain the market's derived demand for live hogs:

$$Q_f^D = A\left(\alpha\left(Q_{r,C}^{D}\right)^{\rho} + (1-\alpha)\left(Q_{r,N}^{D}\right)^{\rho}\right)^{\frac{1}{\rho}}. \tag{3.10}$$

Equilibrium Conditions without Regulations

The following conditions characterize the equilibrium prices and quantities in the baseline case:

$$Q_f^* = Q_f^{D*} = Q_f^{S*};\, P_f^* = P_f^{D*} = P_f^{S*}, \tag{3.11}$$

$$Q_{r,C}^* = Q_{r,C}^{D*} = Q_{r,C}^{S*};\, P_{r,C}^* = P_{r,C}^{D*} = P_{r,C}^{S*}, \tag{3.12}$$

$$Q_{r,N}^* = Q_{r,N}^{D*} = Q_{r,N}^{S*};\, P_{r,N}^* = P_{r,N}^{D*} = P_{r,N}^{S*}, \tag{3.13}$$

$$\frac{Q_{r,C}^*\left(P_{r,C}^* - c_C\right) + Q_{r,N}^*\left(P_{r,N}^* - c_N\right)}{Q_f^*} = P_f^*. \tag{3.14}$$

The asterisks denote equilibrium values. Equations (3.11), (3.12), and (3.13), are market-clearing conditions at the farm and at retail for covered and non-covered products, respectively. Equation (3.14) represents the fundamental condition defining competitive equilibrium. The weighted average of two products' values net of processing costs must equal the price of live hogs.

3.2.2. Market in the Presence of Subnational Regulations

Now consider regulations imposed on products in a subnational jurisdiction, which takes only a portion of the total market demand. The regulated jurisdiction becomes a market separate from the other jurisdictions for covered products because covered products cannot be sold within the regulated jurisdiction unless they satisfy the regulations.[10]

Primary demand for products when regulations are implemented: I denote the share of North American consumption of both products in regulated jurisdiction as δ:

$$Q_{r,C}^{D,R} = \delta Q_{r,C}^{D}, \text{and } Q_{r,C}^{D,U} = (1-\delta) Q_{r,C}^{D}, \tag{3.15}$$

$$Q_{r,N}^{D,R} = \delta Q_{r,N}^{D}, \text{and } Q_{r,N}^{D,U} = (1-\delta) Q_{r,N}^{D}, \tag{3.16}$$

where superscripts R and U denote the regulated market and unregulated market, respectively. The following four inverse demand functions come from equations (3.2), (3.3), (3.15) and (3.16):

$$P_{r,C}^{D,R} = \gamma - \frac{\beta_{cc}}{\delta} Q_{r,C}^{D,R} - \frac{\beta_{cn}}{\delta} Q_{r,N}^{D,R}, \tag{3.17}$$

$$P_{r,C}^{D,U} = \gamma - \frac{\beta_{cc}}{1-\delta} Q_{r,C}^{D,U} - \frac{\beta_{cn}}{1-\delta} Q_{r,N}^{D,U}. \tag{3.18}$$

$$P_{r,N}^{D} = \theta - \frac{\eta_{nn}}{\delta} Q_{r,N}^{D,R} - \frac{\eta_{nc}}{\delta} Q_{r,C}^{D,R}, \tag{3.19}$$

$$P_{r,N}^{D} = \theta - \frac{\eta_{nn}}{1-\delta} Q_{r,N}^{D,U} - \frac{\eta_{nc}}{1-\delta} Q_{r,C}^{D,U}. \tag{3.20}$$

The retail price of non-covered products is assumed to be the same in and outside California because the restrictions of Prop 12 are not required for non-covered products.[11]

---

[10] Consumers near the border of a regulated jurisdiction may shop in a nearby unregulated jurisdiction to avoid higher prices caused by regulation. Studies have provided evidence on cross-border shopping for products such as alcohol (Asplund, Friberg, and Wilander 2007), lotteries (Knight and Schiff 2012), and soft drinks (Lang 2022). To our knowledge, the only study of cross-border shopping for food is Tosun and Skidmore (2007) who reported a small decrease in the revenue from food products when West Virginia changed the sales tax on food products. I expect that the cross-border shopping due to Prop 12 will be minimal because the regulated pork products affect only a small portion of food budgets and opportunities to shop across the state border are limited, given concentrations of population along the Pacific Coast and farm from the bordering states of Arizona, Nevada and Oregon.

[11] I develop the model for the case where demand for covered pork products in the regulated jurisdiction does not shift due to the regulation. An interesting possibility that we explore later is that demand for covered pork products increases in the regulated jurisdiction. For example, in the case of Prop 12, a demand increase could come from consumers who did not eat pork pre-regulation but are willing to eat it post-regulation because they now believe it has been humanely produced.

Supply of farm product with regulations: Each farm *i* chooses whether or not to produce the farm product eligible for use as input into food products destined for the regulated jurisdiction. As noted above, I assume that producing for the regulated jurisdiction entails incurring a fixed conversion cost to reconfigure operations to meet the regulations as well as a higher variable cost per unit because of restriction on housing and farm practices.

Conversion costs differ across farms, for example, because of a difference in a farm's facilities and equipment prior to the regulations. Some farms will have relatively low conversion costs because their extant operations come closer to compliance with the requirements of the regulation than other farms' operations. The average per unit conversion cost is denoted by σ_i, where subscript i indicated the difference across farms. The average per unit cost is the sum of the expected present value of one-time conversion cost per unit, denoted by ϕ_i, and the incremental per unit variable cost, assumed to be constant across farms and denoted by ν:

$$\sigma_i = \phi_i + \nu, \tag{3.21}$$

Without loss of generality, farms are ordered along a continuum from the lowest average conversion cost, $\underline{\phi}$, to the highest, $\overline{\phi}$. For simplicity, the average conversion cost is assumed to be uniformly distributed. That is, each farm i has a cost, $\phi_i \sim U\left[\underline{\phi}, \overline{\phi}\right]$, that characterizes its potential one-time conversion cost of becoming compliant per-unit of the raw product.

Assume that farmers form expectations about prices and quantities of the compliant product and the noncompliant product. Farm i chooses to comply and adopt the restricted practices if

$$\phi_i q_f^R \leq PS^R - PS^U. \tag{3.22}$$

The term q_f^R is the anticipated quantity of compliant hogs supplied by the farm. The term PS^R is the farm level producer surplus of those that convert, and the term PS^U is that of non-converters both assesses under the new equilibrium with Prop 12 in place. That is, a farm converts if the one-time conversion cost is greater than or equal to the producer surplus difference. Otherwise, a farm does not convert, and in that case, it maintains the lower-cost standard practices. Only farms with low costs of conversion will adopt the restricted practices required for compliance, while those with higher costs of conversion continue to use the standard practices. The marginal farm that is indifferent between compliance and non-compliance has the one-time conversion cost $\tilde{\phi} q_f^R$ such that

$$\tilde{\phi} q_f^R = PS^R - PS^U. \tag{3.23}$$

Equation (3.23) has important implications. First, the larger the market share of the regulated jurisdiction, the larger is the critical value, $\tilde{\phi}$, and therefore the larger the implied producer surplus differential must be to elicit sufficient conversion. Second, converting to the restricted production practice increases the producer surplus for converters who are inframarginal to the indifferent adopter. However, if the regulations cause the non-compliant hog price to fall, those converters near the conversion margin lose producer surplus relative to the situation without the regulation. Industry groups generally oppose regulations of this type, as is true for Prop 12, it is noteworthy that, as is often the case, farms with relatively low compliance costs earn higher profits after the regulation than before. Third, restrictions have effects on the unregulated segment of the market through the re-allocation of production and consumption between the regulated and unregulated sectors and between covered and non-covered products.

The supply functions for farms are

$$P_f^{S,U} = a + bq_{f,i}^{S,U}, \tag{3.24}$$

$$P_f^{S,R} = a + \nu + bq_{f,i}^{S,R}, \tag{3.25}$$

where the variable $q_{f,i}^{S}$ is the quantity of hogs supplied by farm i. The supply function for farms that do not comply with the regulation is unaffected. The supply function of individual farms for the regulated jurisdiction shifts up by the incremental variable cost, ν.

The market supply function of farm product from each type of farm is the integration of quantities over farms in each group at each price differential:

$$Q_f^{S,U} = \int_{\tilde{\phi}}^{\overline{\phi}} q_{f,i}^{S,U}\, dF(\sigma_i) = \int_{\tilde{\phi}}^{\overline{\phi}} \left(\frac{P_f^{S,U} - a}{b}\right) dF(\sigma_i) = \left(\frac{P_f^{S,U} - a}{b}\right)(1 - \tilde{\xi}), \tag{3.26}$$

$$Q_f^{S,R} = \int_{\underline{\phi}}^{\tilde{\phi}} q_{f,i}^{S,R}\, dF(\sigma_i) = \int_{\underline{\phi}}^{\tilde{\phi}} \left(\frac{P_f^{S,R} - a - \nu}{b}\right) dF(\sigma_i) = \left(\frac{P_f^{S,R} - a - \nu}{b}\right)\tilde{\xi}, \tag{3.27}$$

where $\tilde{\xi} = \left(\tilde{\phi} - \underline{\phi}\right) / \left(\overline{\phi} - \underline{\phi}\right)$ represents the fraction of farms that convert to utilizing the restricted practices. The inverse aggregate supply functions are

$$P_f^{S,U} = a + \frac{b}{1 - \tilde{\xi}} Q_f^{S,U}, \tag{3.28}$$

$$P_f^{S,R} = a + \nu + \frac{b}{\tilde{\xi}} Q_f^{S,R}. \tag{3.29}$$

<u>Processing and marketing sector with regulations</u>: The model specifies an incremental constant cost per hog to primary processors (superscript p), Δc_C^p, due to additional costs for segregation, certification, recordkeeping, etc. associated with meeting the regulation. Other costs, Δc_C^m, are also incurred for handling compliant pork throughout the downstream marketing (superscript m) chain. Note that non-covered pork produced from compliant hogs is not differentiated in the market from non-covered pork from non-compliant hogs. Hence, Δc_C^p will

be transferred solely through a shift of the supply function of covered pork from compliant hogs, $Q_{r,C}^{S,R}$.[12]:

$$Q_{r,C}^{S,R} = Q_f^{S,R}\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,C}^{S,R} - c_C - \left(\frac{\Delta c_C^p}{\mu^*} + \Delta c_C^m\right)}{\alpha P_f^{S,R}}\right)^{\tau} \text{ where } \mu^* = \frac{Q_{r,C}^*}{Q_{r,C}^* + Q_{r,N}^*}. \qquad (3.30)$$

The asterisk denotes equilibrium values. The sum $\Delta c^p/\mu^* + \Delta c_C^m$ represents the combined incremental per-unit processing and marketing cost associated with producing and marketing covered pork. The other supply functions can be modeled analogously to those without regulations:

$$Q_{r,C}^{S,U} = Q_f^{S,U}\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,C}^{S,U} - c_C}{\alpha P_f^U}\right)^{\tau}, \qquad (3.31)$$

$$Q_{r,N}^{S} = Q_{r,N}^{S,R} + Q_{r,N}^{S,U} = Q_f^{S,R}\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,N}^{S} - c_N}{(1-\alpha)P_f^R}\right)^{\tau} + Q_f^{S,U}\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,N}^{S} - c_N}{(1-\alpha)P_f^U}\right)^{\tau}. \qquad (3.32)$$

where (3.31) denotes the retail supply for covered pork in the unregulated jurisdictions, and (3.32) is total supply for non-covered products.

Analogous to the base without regulations, the derived demand for live hogs can be obtained as follows:

$$Q_f^{D,R} = A\left(\alpha\left(Q_{r,C}^{D,R}\right)^{\rho} + (1-\alpha)\left(Q_{r,N}^{D,R}\right)^{\rho}\right)^{\frac{1}{\rho}}, \qquad (3.33)$$

$$Q_f^{D,U} = A\left(\alpha\left(Q_{r,C}^{D,U}\right)^{\rho} + (1-\alpha)\left(Q_{r,N}^{D,U}\right)^{\rho}\right)^{\frac{1}{\rho}}. \qquad (3.34)$$

Equilibrium Conditions with Regulations

[12] Processors who attempted to raise prices for noncovered products would be undercut by processors who did not participate in the restricted market and, thus, did not incur Δc_C^p.

The following equations characterize the equilibrium quantities and prices, which are analogous to the baseline case, but involve additional equations to reflect separate farm markets for regulated and unregulated product and regulated and unregulated markets for covered product:

$$Q_f^{R*} = Q_f^{D,R*} = Q_f^{S,R*}; P_f^{R*} = P_f^{D,R*} = P_f^{S,R*}, \tag{3.35}$$

$$Q_f^{U*} = Q_f^{D,U*} = Q_f^{S,U*}; P_f^{U*} = P_f^{D,U*} = P_f^{S,U*}, \tag{3.36}$$

$$Q_{r,C}^{R*} = Q_{r,C}^{D,R*} = Q_{r,C}^{S,R*};\ P_{r,C}^{R*} = P_{r,C}^{D,R*} = P_{r,C}^{S,R*}, \tag{3.37}$$

$$Q_{r,C}^{U*} = Q_{r,C}^{D,U*} = Q_{r,C}^{S,U*};\ P_{r,C}^{U*} = P_{r,C}^{D,U*} = P_{r,C}^{S,U*}, \tag{3.38}$$

$$Q_{r,N}^{R*} + Q_{r,N}^{U*} = Q_{r,N}^{D,R*} + Q_{r,N}^{D,U*} = Q_{r,N}^{S*} = Q_{r,N}^{*};\ P_{r,N}^{*} = P_{r,N}^{D*} = P_{r,N}^{S*}. \tag{3.39}$$

Here (3.35) denotes equilibrium in the market for compliant hogs, (3.36) denotes equilibrium for noncompliant hogs, (3.37) represents equilibrium in the consumer market for covered pork products, (3.38) indicates equilibrium conditions for covered products in the unrestricted market, and (3.39) represents equilibrium for non-covered products. Production will enter the regulated market for covered products and exit the unregulated market until the return to the marginal entrant is the same regardless of which type of farm raw material is produced. Hence, the following conditions must hold at the farm and retail markets in equilibrium:

$$\phi^* q_f^{R*} = PS^{R*} - PS^{U*}. \tag{3.40}$$

The final two equations of the model determine the price of live hogs of each type. The weighted average of values of the two products net of processing costs must equal the price of live hogs, where hog quantities and prices are in terms of hundredweight of retail pork.

$$P_f^{R*} = \frac{Q_{r,C}^{R*}\left(P_{r,C}^{R*} - c_C - \left(\frac{\Delta c_C^p}{\mu^*} + \Delta c_C^m\right)\right) + Q_{r,N}^{R*}\left(P_{r,N}^{*} - c_N\right)}{Q_f^{R*}}, \tag{3.41}$$

$$P_f^{U*} = \frac{Q_{r,C}^{U*}\left(P_{r,C}^{U*} - c_C\right) + Q_{r,N}^{U*}\left(P_{r,N}^{*} - c_N\right)}{Q_f^{U*}}. \tag{3.42}$$

3.3. Conclusions

This chapter develops an economic model to analyze the economics of subnational regulations on products sold within the regulating jurisdiction based on production practices. For this purpose, the first section explores essential characteristics of the regulations and the associated food supply chains. Based on the specified characteristics, Section 3.2 develops an economic model.

The model allows (i) the adoption of restricted practices at farms that requires a conversion of capital and (ii) heterogeneity in compliance costs among farms. This conversion is a long-run response of farms and requires a fixed-cost expenditure to convert capital inputs such as reconfiguration of a facility. Farms must forecast the price premium they are likely to receive for their outputs if they convert to the restricted farming practices and determine if the premium will be sufficient to cover both incremental fixed and variable costs of producing the restricted product. Equilibrium conversion is defined by the farm that just breaks even on conversion, given the conversion costs.

This chapter focuses on the case when a mandate only applies to a portion of the output of the live animal. In the model, intermediaries use farm outputs to supply two retail products: covered product and non-covered product. The model allows variable proportions in the production of the two retail products, using the constant elasticity of transformation production possibility frontier. The intermediaries can adjust the production proportion between the two outputs in response to the relative price changes by the regulations.

This model incorporates segregation costs in the processing and marketing sector under regulations. The regulations of interest are imposed at the point of purchase within the regulating jurisdiction, so the identity of compliance must be preserved at all stages along the supply chain. For traceability, segregation between the restricted products and the other products is required. The segregation costs will be transferred mainly to final consumers of covered products in the regulating jurisdiction through a higher retail product price.

The model yields several interesting results. First, the more adoption there is, the higher the farm compliance cost at equilibrium. Second, restrictions raise profits for some inframarginal adopters whose compliance costs are low. Third, restrictions have spillover effects on the unregulated share of the market. Fourth, processing and distribution costs are higher for products covered by regulations, and the magnitude of incremental costs is affected by the size of the regulated jurisdiction. Fifth, competition implies that the cost increases must be borne fully by covered products, and the product coverage of regulations affects its magnitude.

Appendix 3.A. Two Special Cases of the Constant Elasticity of Transformation Production Possibility Frontier

I consider the following constant elasticity of transformation production possibility frontier (equation 3.4 in the paper):

$$q_f = A\left(\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}. \tag{3.A.1}$$

The parameter A is a scale parameter where $A > 0$, the term α is a share parameter where $0 < \alpha < 1$, and the term ρ is a parameter that determines the elasticity of transformation τ where $1 < \rho < \infty$ and $\tau = 1/(\rho - 1)$. As $\rho \to 1$, the CET frontier approaches perfect transformation:

$$q_f = A\left(\alpha q_{r,C} + (1-\alpha) q_{r,N}\right). \tag{3.A.2}$$

Now let us consider the case when $\rho \to \infty$. Equation (3.A.1) yields an indeterminate form, which is ∞^0, as $\rho \to \infty$. To explore this indeterminate form, I will use the L'Hopital's rule. For this purpose, first, take the logarithm:

$$\ln q_f = \ln A + \frac{1}{\rho}\ln\left(\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}\right). \tag{3.A.3}$$

Let us focus on the second term on the right-hand side. According to the L'Hopital's rule, the following relation holds:

$$\begin{aligned}&\lim_{\rho\to\infty}\frac{1}{\rho}\ln\left(\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}\right)\\ &= \lim_{\rho\to\infty}\frac{\alpha\left(q_{r,C}\right)^{\rho}\ln\left(q_{r,C}\right) + (1-\alpha)\left(q_{r,N}\right)^{\rho}\ln\left(q_{r,N}\right)}{\alpha\left(q_{r,C}\right)^{\rho} + (1-\alpha)\left(q_{r,N}\right)^{\rho}}.\end{aligned} \tag{3.A.4}$$

Let us define $M \equiv \max\left(q_{r,C}, q_{r,N}\right)$ where $M > 0$. Dividing both the numerator and denominator by M^{ρ},

$$\lim_{\rho\to\infty} \frac{\alpha\left(q_{r,C}\right)^{\rho}\ln\left(q_{r,C}\right)+(1-\alpha)\left(q_{r,N}\right)^{\rho}\ln\left(q_{r,N}\right)}{\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}}$$

$$= \lim_{\rho\to\infty} \frac{\alpha\left(\frac{q_{r,C}}{M}\right)^{\rho}\ln\left(q_{r,C}\right)+(1-\alpha)\left(\frac{q_{r,N}}{M}\right)^{\rho}\ln\left(q_{r,N}\right)}{\alpha\left(\frac{q_{r,C}}{M}\right)^{\rho}+(1-\alpha)\left(\frac{q_{r,N}}{M}\right)^{\rho}}. \quad (3.A.5)$$

Without loss of generality, assume $q_{r,C} > q_{r,N}$. Because $M = \max\left(q_{r,C}, q_{r,N}\right)$, the term $\left(q_{r,C}/M\right)^{\rho} \to 1$ and $\left(q_{r,N}/M\right)^{\rho} \to 0$ as $\rho \to \infty$. Then,

$$\lim_{\rho\to\infty} \frac{\alpha\left(\frac{q_{r,C}}{M}\right)^{\rho}\ln\left(q_{r,C}\right)+(1-\alpha)\left(\frac{q_{r,N}}{M}\right)^{\rho}\ln\left(q_{r,N}\right)}{\alpha\left(\frac{q_{r,C}}{M}\right)^{\rho}+(1-\alpha)\left(\frac{q_{r,N}}{M}\right)^{\rho}} = \lim_{\rho\to\infty}\frac{\alpha\ln\left(q_{r,C}\right)}{\alpha} = \ln\left(q_{r,C}\right) = \ln M\,. \quad (3.A.6)$$

Similarly, the same result can be obtained when $q_{r,C} \leq q_{r,N}$. Then, from (6.A.2), $\ln q_f = \ln A + \ln M = \ln AM$. Or,

$$q_f = AM = A\max\left(q_{r,C}, q_{r,N}\right). \quad (3.A.7)$$

Hence, as $\rho \to \infty$, the CET frontier approaches fixed proportions.

Appendix 3.B. Derivation of the Supply Functions of Hog Carcass Used for Covered and Non-Covered Pork

Processing plants maximize the revenue of their two outputs:

$$\max_{q_{r,C},q_{r,N}} \left(P_{r,C}-c_C\right)q_{r,C}+\left(P_{r,N}-c_N\right)q_{r,N} \text{ subject to}$$

$$\overline{q}_f = A\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}} \text{ where } A>0, 0<\alpha<1, \text{and } 1<\rho<\infty. \quad (3.B.1)$$

From the Lagrangian

$$\Lambda = \left(P_{r,C}-c_C\right)q_{r,C}+\left(P_{r,N}-c_N\right)q_{r,N}-\lambda\left(A\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}-\overline{q}_f\right). \quad (3.B.2)$$

The first order conditions are

$$\frac{\partial\Lambda}{\partial q_{r,C}} = \left(P_{r,C}-c_C\right)-\lambda A\left(\frac{1}{\rho}\right)\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}-1}\alpha\rho\left(q_{r,C}\right)^{\rho-1}=0, \quad (3.B.3)$$

$$\frac{\partial\Lambda}{\partial q_{r,N}} = \left(P_{r,N}-c_N\right)-\lambda A\left(\frac{1}{\rho}\right)\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}-1}(1-\alpha)\rho\left(q_{r,N}\right)^{\rho-1}=0, \quad (3.B.4)$$

$$\frac{\partial\Lambda}{\partial\lambda} = -\left(A\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}-\overline{q}_f\right)=0. \quad (3.B.5)$$

From (3.B.3) and (3.B.4), I obtain

$$\frac{P_{r,C}-c_C}{P_{r,N}-c_N} = \frac{\alpha}{1-\alpha}\left(\frac{q_{r,C}}{q_{r,N}}\right)^{\rho-1}. \quad (3.B.6)$$

Or,

$$q_{r,N} = \left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{1}{\rho-1}} q_{r,C}. \quad (3.B.7)$$

Substituting $q_{r,N}$ from (3.B.7) for $q_{r,N}$ in (3.B.5) yields

$$\overline{q}_f = A\left(\alpha\left(q_{r,C}\right)^{\rho}+(1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{\rho}{\rho-1}}\left(q_{r,C}\right)^{\rho}\right)^{\frac{1}{\rho}}. \quad (3.B.8)$$

After steps of algebra, I obtain

$$q_{r,C} = \frac{\bar{q}_f}{A}\left(\alpha + (1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}}. \tag{3.B.9}$$

Because (3.B.9) is satisfied for every $\bar{q}_f$,

$$q_{r,C} = \frac{q_f}{A}\left(\alpha + (1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}}. \tag{3.B.10}$$

The relation, $\tau = 1/(\rho - 1)$, yields:

$$q_{r,C} = \frac{q_f}{A}\left(\alpha + (1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\tau+1}\right)^{-\frac{\tau}{\tau+1}}. \tag{3.B.11}$$

(3.B.11) is the output-constant industry supply of the hog carcass used for uncooked cuts of pork. Because of the homogeneity among intermediaries, I obtain the derived supply function of uncooked cuts of pork as follows:

$$Q_{r,C} = \frac{Q_f}{A}\left(\alpha + (1-\alpha)\left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\tau+1}\right)^{-\frac{\tau}{\tau+1}}. \tag{3.B.12}$$

This is the expression of equation (3.6) in the paper. Similarly, the derived supply function of non-covered pork can be obtained as follows:

$$Q_{r,N} = \frac{Q_f}{A}\left((1-\alpha) + \alpha\left(\frac{1-\alpha}{\alpha}\frac{P_{r,C}-c_C}{P_{r,N}-c_N}\right)^{\tau+1}\right)^{-\frac{\tau}{\tau+1}}. \tag{3.B.13}$$

(3.B.13) is the expression of equation (3.7) in the body of the chapter.

Appendix 3.C. Derivation of the Supply Function of Hog Carcass Used for Covered Pork as a Function of the Price of Live Hogs

The price of live hogs, P_f, is the average of $P_{r,C} - c_C$ and $P_{r,N} - c_N$, weighted by the corresponding quantity shares:

$$P_f = \frac{Q_{r,C}\left(P_{r,C} - c_C\right) + Q_{r,N}\left(P_{r,N} - c_N\right)}{Q_f}. \qquad (3.C.1)$$

Using the derived supply functions of covered and non-covered pork, I obtain

$$P_f = \frac{\left(P_{r,C} - c_C\right)\frac{Q_f}{A}\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{1}{\rho-1}} T + \left(P_{r,N} - c_N\right)\frac{Q_f}{A}\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{1}{\rho-1}} T}{Q_f}$$

$$= \left(P_{r,C} - c_C\right)\frac{1}{A}\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{1}{\rho-1}} T + \left(P_{r,N} - c_N\right)\frac{1}{A}\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{1}{\rho-1}} T$$

$$= \frac{T}{A}\left(\left(P_{r,C} - c_C\right)\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{1}{\rho-1}} + \left(P_{r,N} - c_N\right)\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{1}{\rho-1}}\right)$$

$$= \frac{T}{A}\left(\alpha\frac{P_{r,C} - c_C}{\alpha}\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{1}{\rho-1}} + (1-\alpha)\frac{P_{r,N} - c_N}{1-\alpha}\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{1}{\rho-1}}\right)$$

$$= \frac{T}{A}\left(\alpha\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right),$$

where

$$T = \left(\alpha\left(\frac{P_{r,C} - c_C}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{P_{r,N} - c_N}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{-\frac{1}{\rho}}.$$

Because $T^{-\rho} = \alpha\left(\frac{P_{r,C}-c_C}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{P_{r,N}-c_N}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}$, I obtain

$$P_f = \frac{T}{A}T^{-\rho} = \frac{T^{1-\rho}}{A} = \frac{1}{A}\left(\alpha\left(\frac{P_{r,C}-c_C}{\alpha}\right)^{\frac{\rho}{\rho-1}} + (1-\alpha)\left(\frac{P_{r,N}-c_N}{1-\alpha}\right)^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}.$$

Note that $\left(\frac{1}{\gamma}\right)^{\frac{1}{\rho-1}}\left(\frac{1}{P_f}\right)^{\frac{1}{\rho-1}} = T$. Hence, the supply function of covered pork can be written as:

$$Q_{r,C} = \frac{Q_f}{A}\left(\frac{P_{r,C}-c_C}{\alpha}\right)^{\frac{1}{\rho-1}}\left(\frac{1}{A}\right)^{\frac{1}{\rho-1}}\left(\frac{1}{P_f}\right)^{\frac{1}{\rho-1}} = Q_f\left(\frac{1}{A}\right)^{\frac{\rho}{\rho-1}}\left(\frac{P_{r,C}-c_C}{\alpha}\right)^{\frac{1}{\rho-1}}\left(\frac{1}{P_f}\right)^{\frac{1}{\rho-1}}.$$

Because we know $\tau = 1/(\rho-1)$, the supply function of covered pork can be rewritten as:

$$Q_{r,C} = Q_f\left(\frac{1}{A}\right)^{1+\tau}\left(\frac{P_{r,C}-c_C}{\alpha P_f}\right)^{\tau}. \qquad (3.C.2)$$

This is the expression of equation (3.8) in the paper. Similarly, I derive the derived supply function of non-covered pork, equation (3.9) in the body of the chapter.

References

Asplund, M., R. Friberg, and F. Wilander. 2007. "Demand and Distance: Evidence on Cross-Border Shopping." *Journal of Public Economics* 91: 141-157.

California Health and Safety Code. 2009. Division 20, Chapter 13.8, Section 25990-25991.

Informa Economics. 2010. Update of Cost Assessments for Country of Origin Labeling – Beef and Pork. Included as Exhibit CDA-70. Available at: http://www.informaecon.com/CoolReport2010.asp.

Knight, B., and N. Schiff. 2012. "Spatial Competition and Cross-Border Shopping: Evidence from State Lotteries." *American Economic Journal: Economic Policy* 4(4): 199-229.

Lang, H. 2022. "The Impact of Soda Taxes in the U.S.: Empirical Evidence and Comparison Across Jurisdictions." Ph.D. Dissertation, University of California, Davis.

Pendell, D. L., G. W. Brester, T. C. Schroeder, K. C. Dhuyvetter, and G. T. Tonsor. 2010. "Animal Identification and Tracing in the United States." *American Journal of Agricultural Economics* 92(4): 927-940.

Powell, A. A., and F. H. G. Gruen. 1968. "The Constant Elasticity of Transformation Production Frontier and Linear Supply System." *International Economic Review* 9(3): 315-328.

Rickerd, B. J., and D. A. Sumner. 2008. "Domestic Support and Border Measures for Processed Horticultural Products." *American Journal of Agricultural Economics* 90(1): 55-68.

Saitone, T. L., R. J. Sexton, and D. A. Sumner. 2015. "What Happens When Food Marketers Require Restrictive Farming Practices?" *American Journal of Agricultural Economics* 97(4): 1021-1043.

Sexton, R. J., and T. Xia. 2018. "Increasing Concentration in the Agricultural Supply Chain: Implications for Market Power and Sector Performance." *Annual Review of Resource Economics* 10: 229-251.

Sumner, D. A., and T. Zuijdwijk. 2019. "The Law and Economics of Canada's WTO Litigation Contesting U.S. Country-Of-Origin Labeling (COOL)." *Canadian Journal of Agricultural Economics* 67: 327-347.

Tomek, W. G., and H. M. Kaiser. 2014. *Agricultural Product Prices*. NY: Cornell University Press.

Tosun, M., and M. L. Skidmore. 2007. "Cross-Border Shopping and the Sales Tax: An Examination of Food Purchases in West Virginia." *B.E. Journal of Economic Analysis & Policy* 7(1), Article 63.

Wohlgenant, M. K. 1989. “Demand for Farm Output in a Complete System of Demand Functions.” *American Journal of Agricultural Economics* 71(2): 241-252.

Wohlgenant, M. K. 1993. “Distribution of Gains from Research and Promotion in Multi-Stage Production Systems: The Case of the U.S. Beef and Pork Industries.” *American Journal of Agricultural Economics* 75: 642-651.

Wohlgenant, M. K. 2013. “Competition in the US Meatpacking Industry.” *Annual Review of Resource Economics* 5:1-12.

Chapter 4. The Impact of California's 2022 Pork Rules on the North American Hog/Pork Supply Chain

The previous chapter develops an economic model to analyze the impacts of subnational regulations on farming practices for products sold within the jurisdiction. Using the model, this chapter evaluates the impacts of California's Proposition 12 regulations on pork products for an application. Section 4.1 explains how to calibrate the model. Section 4.2 reports the simulation results and provides implications of Prop 12 for producers and consumers. Section 4.3 examines implications about farm treatment of sows. The last section concludes.

4.1. Model Calibration[1]

The economic model developed in Chapter 3 is used to simulate the impacts of Prop 12. The model was calibrated around 2018 values for hog production and pork consumption in Canada and the United States. Imports and exports of pork products from the two countries were also incorporated at 2018 values under the assumption that these trade volumes are fixed, as was assumed in Wohlgenant (1993) and Saitone, Sexton, and Sumner (2015). After the U.S. country of origin labeling was eliminated in 2015, the North American hog and pork markets have been once again integrated so that my modeling the implication of regulations reflects that integration. Assuming fixed net exports is consistent with very small price impacts in the non-regulated segment of the North American market.

4.1.1. Calibration of the Primary Supply and Demand Functions

[1] Appendix 4.D provides additional information on parameter specification.

The parameters (intercepts and slopes) of the primary supply and demand functions were calibrated such that the functions fit the 2018 market values for North America, based on Canadian and U.S. government statistics, and have the corresponding price elasticity given those values. I used a price elasticity of supply of hogs at the farm of 1.8 from Lemieux and Wohlgenant (1989), which was used in subsequent work (e.g., Wohlgenant 1993; Saitone, Sexton, and Sumner 2015).[2]

To parameterize the primary demand functions, I began with a base retail price elasticity of demand for all pork of -0.68 from Okrent and Alston (2011), a value that compares closely to values of -0.69 and -0.79 used by Buhr (2005) and -0.65 reported by Wohlgenant and Haidacher (1989). The demands for covered and non-covered pork products will be more price elastic than the demand for pork as an aggregate category based on consumers' willingness to substitute between the two types of pork products in response to price signals. After reviewing the relevant literature, I chose a base value of -0.9 for covered pork and -1.1 for non-covered pork.[3] Given Okrent and Alston's estimate of the price elasticity of demand for all pork and the market shares for C and N pork, these values imply a cross-price elasticity of 0.36 for N pork demand in response to a change in the price of covered pork and a cross-price elasticity of 0.26 for C pork demand in response to a change in the price of non-covered pork.

[2] Price elasticity of supply for most products depends upon the length of time producers have to adjust to a price change. Opportunities to adjust production in response to price changes increase as the time horizon is expanded. Saitone, Sexton, and Sumner (2015) argue that this estimate reflects of an intermediate-run horizon that allows the industry a range of adjustment to buyers (in their case), or political jurisdictions in our case, requiring the industry to adopt restrictive production practices. Notably implementation of the Proposition was delayed three years from passage to allow a range of industry adjustment.

[3] A few studies have addressed demand for individual pork products and estimated the degree of consumer substitution among them in response to price changes. Nayga and Capps (1994) examined the demand for pork products based on data for a retail store in Houston, Texas. Hailu et al. (2014) studied demand for pork products in Canada based on a panel of Canadian consumers. Both studies showed a modest willingness on consumers' parts to substitute among alternative pork products.

4.1.2. Calibration of the Derived Supply and Demand Functions

The derived supply and demand functions are characterized by the primary (farm) supply and (retail) demand functions and five additional parameters: the processing and marketing margins of the two products, c_C and c_N, and the scale parameter, A, share parameter, α, and elasticity parameter, ρ, associated with the CET function. The difference between the 2018 average retail price and the 2018 average farm price was used to calibrate the per-unit marketing margins, c_C and c_N (each measured in terms of retail weight per cwt.). This calibration approach assumes that the net price of covered pork after excluding the processing and marketing margin, $P_{r,C} - c_C$, equals that of non-covered pork, $P_{r,N} - c_N$. Processors' ability to substitute in production between C and N pork through the CET function ensures that this condition holds in equilibrium.[4]

The parameter ρ was calibrated given the elasticity of transformation, τ, and the relation, $\tau = 1/(\rho - 1)$. Based on my interviews with industry personnel, I utilized $\tau = 0.5$ to reflect an intermediate-run horizon that allows the intermediaries some ability to adjust production proportions between C and N pork products. The share parameter α was calibrated given τ, the base output quantities, and the net prices of the two products: $P_{r,C} - c_C$ and $P_{r,N} - c_N$. Finally, the scale parameter A was calibrated given τ, α, and the hog input and output quantities. See Appendix 4.B for detailed calibration procedures.[5]

4.1.3. Costs of Compliance with Prop 12

[4] Appendix 4.A reports a sensitivity analysis using different ratios of the two expressions, $P_{r,C} - c_C$ and $P_{r,N} - c_N$. The sensitivity analysis shows that simulation results are robust to reasonable choices of the ratios.

[5] I considered sensitivity to using different values of τ, which demonstrated the robustness of the simulation results to reasonable choices of τ (See Appendix 4.C).

Based on the size of the California pork market relative to the total market for covered pork products produced in North America, about 7% to 8% of North American sow housing needs to be compliant with Prop 12 standards to meet California's demand. Generally, compliance would be less costly for farms already using group housing than for farms using gestation stalls. Therefore, Prop-12 compliant farms will mostly come from the set already using group housing. Hence, the relevant one-time cost of conversion to Prop 12's requirements is that which applies to group housing operations. Variable costs for group-housing operations that become Prop-12 compliant are also compared with those that remain non-compliant.

The major increase in capital recovery costs due to Prop 12 comes from fewer sows using a facility. Based on information from the industry, about 20 square feet of usable space per sow is allowed among typical operations using group housing, with some variation below that space per sow. Capital costs of housing per sow for those mostly likely to convert will, thus, rise by about 20% to increase the space allowance per sow from 20 to 24 square feet. Based on farm cost data (Tonsor and Reid 2020; USDA-ERS 2021a), the implied increase in capital costs were assessed to be $3 per piglet produced in a farrowing operation, when converted to a marketed weight basis this corresponds to ϕ in my model.

As noted, compliance costs vary across farms based on farm-specific characteristics such as housing facilities and managerial expertise. Given that less than 10% of North American hogs are destined for California consumption, I assumed that farms covering roughly 30% of the total North American sows might seriously consider the option to produce Prop 12-compliant sows. I use $2 per pig as the lowest conversion cost and $5 per pig as the cost for the 30th percentile of farrowing operations (those with group housing). The calculated value ($3 per pig) for group housing with 20 square feet per sow, therefore, is consistent with the lower 10th percentile of the uniform distribution. Note that hog farms with a higher cost of conversion, say those using gestation stall housing, are irrelevant to the calculations because they are far outside the range of farms that might convert to compliance. The bounds of the uniform distribution are $\underline{\phi} = \$2$ per pig or \$1.24 per cwt. of marketable pork and $\overline{\phi} = \$5$ per pig or \$3.11 per cwt. (On average, each hog produces 160.8 pounds of marketable pork.)

Prop 12 raises variable costs per pig produced in several ways. These include higher sow mortality, lower farrowing rates, fewer live pigs per sow, higher veterinarian costs, and higher farm labor costs all assessed on a marketable per pig basis. To compare costs, I used as the baseline costs calculated by university specialists (Tonsor and Reid 2020). Based on productivity information from producers, including declarations from dozens of producers included in the Petitioners Complaint in UNITED STATES DISTRICT COURT SOUTHERN DISTRICT OF CALFIORNIA CASE NO. 19CV2324W AHG National Pork Producers Council and the American Farm Bureau Federation v. Ross Dated: December 5, 2019. Based on these sources, I assessed the addition to variable cost to be about \$2 per pig, which corresponds to a ν of \$1.24 per cwt. of marketable pork.

4.1.4. Additional Costs of Processing and Marketing Prop 12-Compliant Pork

Given that California comprises less than 10% of the North American retail pork market, many primary processing operations will choose not to acquire the costly Prop 12-compliant hogs. These plants will avoid added costs of identifying, segregating, tracing, and labeling the compliant pork separately from the rest of their production.

Most primary processing operations that do acquire and process the more expensive compliant hogs will also continue to utilize noncompliant hogs to exploit economies of size, access hogs within a reasonable distance of the plant to reduce transport costs and utilize plant capacity efficiently. These firms thus incur additional costs for identification, segregation, and tracing to enable sales of compliant pork into the California market. Such costs include separate holding pens, more complicated and less flexible scheduling, interruption in plant operation between processing the compliant and non-compliant hogs, additional storage capacity so that the up-to-double SKUs of fresh pork can be kept in distinct lots, a more complicated labeling process, and more complex shipping of labeled products.

The costliest among these factors is likely to be the interruption of plant operations and reduced throughput during the change-over from handling compliant to non-compliant hogs. Compliant hogs will be processed on different days and/or at different times on a given day from other hogs to assure that non-compliant pork is not comingled with uncooked cuts of pork that are destined for California. Based on my surveys and interviews, the additional cost, Δc_C^p, is assessed to be about \$15 per compliant hog slaughtered, or \$0.09 per pound of hog carcass (retail weight equivalent). The surveys and interviews with secondary processors and marketers suggest additional costs for handling compliant pork downstream from the primary processing operation, Δc_C^m, are about \$0.05 per pound of Prop 12-compliant uncooked cuts of pork.

4.2. Simulated Impacts of Proposition 12 for Producers and Consumers

4.2.1. Baseline Scenario

Table 4.1 presents the simulation results for my main scenario with what I consider the best set of parameters. Naturally, variations in these results follow from alternative parameter sets, and I explore that sensitivity in the appendixes. The model projects that the average farm price equivalent of Prop 12-compliant pork will rise by 3.5%, or about \$2.74 per cwt in base year

(2018) dollars. However, it projects almost no change in the price of non-compliant hogs or pork. Further, my simulation projects that the average price of uncooked (i.e., covered) cuts of pork in California will rise by 6.9%, or about $0.23 per pound (again in base year prices). California consumers will buy 6.2% less of the covered pork products as a consequence, given the baseline price elasticity of demand. Accordingly, the share of North American hogs that provide pork products destined for California will decline from about 7.6% to 7.1%.[6]

This reduction in the share of market hogs destined for California drives much of the small impact of Prop 12 on the rest of the North American market. Because covered pork products cost more in California post Prop 12 and consumers buy less of it, less of North American pork production is used to feed California with Prop 12 than without Prop 12 regulations in place. This means that more of the pork production capacity is available to supply the rest of the market, causing noncompliant hog prices to fall by about 0.3% (about $0.20/cwt. relative to a price of about $79.20/cwt. per hog). Retail prices for noncompliant pure pork products to decline by about 0.2%. The lower consumer price causes a small percentage increase in quantity demanded, but, given that the non-California share of the market exceeds 90%, this increase largely offsets the decrease in consumption in California, so that the model predicts only a 0.2% decline in hog production due to Prop 12.[7]

As noted, the more efficient operations that convert to Prop 12 compliance can expect to increase profits from conversion, while marginal converters should on expectation breakeven from conversion. The model estimates that converting operations gain about $0.2 million

---

[6] The conversion condition (equation 3.22) assumes that farms with lower conversion costs participate in the California market. However, some farms with low conversion costs may not convert because of contractual reasons and, instead, farms with relatively high conversion costs may convert. I acknowledge that the neglection of those farms may underestimate the impact of Prop 12 on the North American hog market. For sensitivity analysis, Appendix 4.E presents simulation results when some farms may not convert due to contractual reasons.

[7] Note that the model and simulation results do not incorporate impacts due to possible disequilibrium conditions at the time Prop 12 is implemented if it survives Supreme Court review.

annually in producer surplus in 2018 dollars from converting to compliance with Prop 12 and supplying pork to California. Those that continue to produce for the unregulated market will lose a small amount of surplus due to the slightly lower hog price. I estimate that this aggregate loss to those that do not supply the California market about $44.8 million annually. The resulting in a net annual loss to producers of about $44.6 million or about $0.16 loss per hog. Despite significant industry opposition, Prop 12 will not impose much negative impact on producers on average.

The California covered pork price increase implies that California consumers of covered pork products will have a $258 million consumer surplus loss annually through paying more for less covered pork. However, the higher price of covered pork causes an increase in the California demand of the substitute, non-covered pork. California buyers of non-covered pork are now willing to pay more for non-covered pork and quantity demand rises by about 2.4%. With our base-case parameters, the consumer surplus gain from the shift in demand for non-covered pork is about $69 million annually. Therefore, the total annual consumer surplus loss for California consumers of the two types of pork is about $188 million or about $4.70 each if all Californians were to eat pork.[8, 9] The per capital impact of Prop 12 on pork consumers outside California will be minimal due to the tiny projected decline in prices uncooked pork cuts outside of California and essentially no change in the price of non-covered pork products.

[8] In simulations, I implicitly assume that prices of other products (substitutes and complements such as eggs, chicken, beef, cheese, and other foods) are given and constant. If the displacement of the pork market affects the prices of other products, the changes in the other product prices will induce cross-price effects in the pork market. I may instead interpret our aggregate pork demand parameters as a representing a general equilibrium demand function. The estimation of the demand parameters is imprecise enough to be consisted with that interpretation.

[9] This estimate of consumer loss does not account for the possibility that less variety of pork products will be sold in California after the implementation of Prop 12 because it may not be worth the cost of supplying the full range of niche uncooked pork cuts from hogs compliant with Prop 12.

4.2.2. Can Subnational Animal Welfare Regulations Increase Profits for All Producers?

The model assumes that the implementation of Prop 12 does not shift California's demand for covered pork products. The projected decrease in consumption arises from movement along the static demand curve due to higher prices. The resultant decrease in California quantity of pork demanded causes the small decrease in hog prices for noncompliant producers and loss of producer surplus.

It is possible that Prop 12 or animal welfare regulations more generally could increase demand for the covered products. For example, some non-consumers of pork in California could become consumers and some who consume pork only occasionally could become more regular consumers upon implementation of Prop 12 because they believe pork for sale California is now more humanely produced.[10]

I explore this potential demand expansion by considering a rotation of the demand function of covered pork in the California market. This is implemented simply by adjusting the coefficient on the covered pork product quantity term in equation (3.17). I rotate this demand curve enough to generate sufficient increases in prices and quantities at the new equilibrium such that the producer surplus of non-compliant hog producers is unchanged under Prop 12. The full results from this exercise are shown in Table 4.2. The large and important changes are that the quantity of California uncooked pork now rises by about 8.3% rather than falling by about 6.2% as was the case in the Table 4.1 results. Also, the quantity of non-covered pork in California falls by 3.2% rather than rising by 2.4% because of the shift in preferences for covered pork production under the assumption that consumers now believe such pork is more humanely

[10] Of course, all the publicity about how hogs are treated on farms could have the opposite effect and reduce all pork consumption in California.

produced. Notice also that producers that supply the California market for covered products gain even more producer surplus so that producers as a group gain about $4.6 million per year.

Table 4.1. Impacts of Proposition 12 on Hog and Pork Prices and Outputs, and Producer Surplus

Variable	Unit	Base	Prop 12	Percent Change
Prices				
Average price, all slaughter hogs	$/cwt	79.20	79.20	0.001
Price, hogs for California pork	$/cwt	79.20	81.94	3.5
Price, hogs for non-California pork	$/cwt	79.20	78.99	-0.3
Average retail price, uncooked cuts of pork	$/lb	3.30	3.32	0.6
Retail price, California uncooked cuts	$/lb	3.30	3.53	6.9
Retail price, non-California uncooked cuts	$/lb	3.30	3.30	-0.2
Retail price, non-covered pork	$/lb	3.79	3.80	0.1
Quantities				
Retail weight equivalent, hog production	million cwt	233.1	232.7	-0.2
for California	million cwt	17.6	16.4[a]	-6.9
for non-California	million cwt	166.0	166.7	0.4
for net export	million cwt	49.5	49.5[b]	0
Share of hogs for the California market	%	7.6	7.1	-6.7
Uncooked cuts share in compliant hog carcass	%	66.2	66.6	0.7
Retail uncooked pork cuts	billion lb	15.42	15.37	-0.5
California retail uncooked pork cuts	billion lb	1.17	1.10	-6.2
Non-California retail uncooked pork cuts	billion lb	9.54	9.56	0.2
Net export, uncooked pork cuts	billion lb	4.72	4.72	0
Retail non-covered pork	billion lb	7.66	7.90	0.1
California non-covered pork	billion lb	0.84	0.86	2.4
Non-California non-covered pork	billion lb	6.82	6.81	-0.2
Net export, non-covered pork	billion lb	0.23	0.23	0
Changes in Producer and Consumer Welfare				
Net gain, total	$ million	-44.6		
Net gain, converters	$ million	0.205		
Net gain, non-converters	$ million	-44.8		
Consumer surplus change, total, CA	$ million	-188.14		
Covered pork	$ million	-257.55		
Non-covered pork	$ million	69.41		
Consumer surplus change, total, non-CA	$ million	17.96		
Covered pork	$ million	63.43		
Non-covered pork	$ million	-45.47		
Consumer surplus change, total, all	$ million	-170.18		
Covered pork	$ million	-194.12		
Non-covered pork	$ million	23.94		

Notes: Prop 12 requires that uncooked cuts of pork sold in California must come from compliant hogs. Prop 12 does not regulate other pork products, which are denoted as "non-covered pork" in this table. I use million cwt for hog production quantity and billion pounds for retail pork quantity in units.

a. The retail weight of hogs produced under California standards.

b. I assume that the net export quantity is fixed and that net exports come from non-compliant hogs.

Table 4.2. Impacts of Proposition 12 on Hog and Pork Prices and Outputs, and Producer Surplus When the California Uncooked Cut Demand Expands so that the Producer Surplus of Non-Compliers does not Decline with the Implementation of Prop 12

Variable	Unit	Base	Prop 12	Percent Change
Prices				
Average price, all slaughter hogs	$/cwt	79.20	79.44	0.3
Price, hogs for California pork	$/cwt	79.20	82.21	3.8
Price, hogs for non-California pork	$/cwt	79.20	79.20	0
Average retail price, uncooked cuts of pork	$/lb	3.30	3.33	0.9
Retail price, California uncooked cuts	$/lb	3.30	3.54	7.2
Retail price, non-California uncooked cuts	$/lb	3.30	3.30	0.1
Retail price, non-covered pork	$/lb	3.79	3.79	-0.1
Quantities				
Retail weight equivalent, hog production	million cwt	233.1	232.9	0.3
for California	million cwt	17.6	18.9[a]	7.2
for non-California	million cwt	166.0	165.5	-0.3
for net export	million cwt	49.5	49.5[b]	0
Share of hogs for the California market	%	7.6	8.1	6.8
Uncooked cuts share in compliant hog carcass	%	66.2	66.9	1.1
Retail uncooked pork cuts	billion lb	15.42	15.51	0.6
California retail uncooked pork cuts	billion lb	1.17	1.26	8.3
Non-California retail uncooked pork cuts	billion lb	9.54	9.53	-0.1
Net export, uncooked pork cuts	billion lb	4.72	4.72	0
Retail non-covered pork	billion lb	7.66	7.88	-0.2
California non-covered pork	billion lb	0.84	0.81	-3.2
Non-California non-covered pork	billion lb	6.82	6.84	0.2
Net export, non-covered pork	billion lb	0.23	0.23	0
Changes in Producer and Consumer Welfare				
Net gain, total	$ million	4.6		
Net gain, converters	$ million	4.6		
Net gain, non-converters	$ million	0		
Consumer surplus change, total, CA	$ million	19.3		
Covered pork	$ million	26.9		
Non-covered pork	$ million	-7.7		
Consumer surplus change, total, non-CA	$ million	4.7		
Covered pork	$ million	-39.2		
Non-covered pork	$ million	43.9		
Consumer surplus change, total, all	$ million	24.0		
Covered pork	$ million	-12.2		
Non-covered pork	$ million	36.2		

Notes: Prop 12 requires that uncooked cuts of pork sold in California must come from compliant hogs. Prop 12 does not regulate other pork products, which are denoted as "non-covered pork" in this table. I use million cwt for hog production quantity and billion pounds for retail pork quantity in units.

a. The retail weight of hogs produced under California standards.

b. I assume that the net export quantity is fixed and that net exports come from non-compliant hogs.

4.3. Implications of Proposition 12 for Farm Treatment of Sows

4.3.1. Farm Treatment of Sows under Proposition 12

Although one major requirement of Prop 12 is no use of gestation stalls for sows that produce pigs destined to supply the California covered pork market, my work shows that Prop 12 will have negligible effects on the conversion of stall housing operations. Given that about 30% of breeding pigs in North America are already confined in group housing, and only about 7-8% of the North American hog production is needed for the California market, operations converting to Prop 12 requirements will come (almost completely) from this group of producers.

Prop 12 will provide more space to breeding pigs in those operations that convert to compliance because the space allowance per sow in typical group housing is smaller than California's 24 square feet minimum requirement. Given that about 7.1% of pork with be produced Prop 12 rules (Table 7.1), this implies about 0.54 million of 7.6 million sows in North America will be confined under California's housing standards. California pork consumers will pay about $188 million annually to provide four square feet more per sow on average for about 540 thousand sows in North America. Thus, California buyers of covered pork will pay about $87 per square foot ($188 million/2.16 million square feet) of additional housing space.[11]

4.3.2. Policies Addressing the Farm Treatment of Hogs (Intended to Improve Animal Welfare)

The passage of Prop 12 in California by a significant majority indicates citizens' interests in improving animal welfare. Regulations such as Prop 12 and its counterparts in other states such

[11] One way to lend context to this estimate is that California's most expensive urban real estate is in San Francisco where annual rents are about $50 per square foot. California pork consumers will pay about twice as much per sow for each extra square foot of space Prop 12 provides.

as Massachusetts and Arizona that set production standards for animal products consumed within the state are, however, only one among a set of possible policy instruments to improve animal welfare by, e.g., allowing them more space. I explore briefly one specific policy alternative to Prop 12: the California state government could, through taxation, simply provide a fund to directly subsidize farms that convert their housing practices to the standards specified in Prop 12.[12]

The subsidies could be distributed through a sealed-bid, second-price or Vickrey auction (e.g., Milgrom 2004). Under this policy, farms in North America could submit a bid per sow for a subsidy from California to convert their operation to comply with the regulations specified in Prop 12. Lowest bids would be accepted until the available funds were expended, and the winning bids would receive a per sow subsidy for conversion equal to the lowest unsuccessful bid. This second-price characteristic induces bidders to submit their valuation of the subsidy, i.e., to bid their estimated conversion cost per sow.[13]

Under the conversion continuum specified in my economic model, each farm i has a per cwt. of pork complying with Prop 12 σ_i where $\sigma_i = \phi_i + \nu$. Such a farm therefore bids $\sigma_i \times q_i$, where q_i is the cwt. per sow that farm i commits to convert to Prop 12 compliance. The auction accepts bids until the revenue committed to the program is exhausted. Suppose that R = \$188 million, which is an amount equal to my simulated loss in California consumer surplus for covered pork products from Prop 12. Then the payment per converting sow is R/N^* where N^* is the number of sows that convert. Clearly, N^* is just the total number of breeding sows, N, in the North American market times the fraction that converts. For simplicity, assume that the number

[12] Similarly, under its Low Carbon Fuel Subsidy program, California pays farms and others to reduce methane emissions no matter where in North America such emissions would have been generated.
[13] This result follows because a participant's bid does not determine the amount of subsidy received, but only if the farm is a winning bidder.

of pounds of pork per sow per year is the same over the converters, $q_i = \bar{q}$. Then, this expression needs to equal to the bid price, $\sigma^A \times \bar{q}$, of the marginal converter:

$$\sigma^A \times \bar{q} = \frac{R}{N \times \left(\frac{\sigma^A - \underline{\sigma}}{\overline{\sigma} - \underline{\sigma}} \times 0.3\right)} . \tag{4.1}$$

Recall that the uniform distribution of conversion costs covers the 30% of all North American farrowing operations using group housing.

Given that I have data on all the values in this expression except for σ^A, the expression can be solved for σ^A to determine how many sows can move from existing housing into Prop 12-compliant housing and compare it to the number from Prop 12.[14] Solving the expression, I obtain σ^A = \$3.67 per cwt., and $\sigma^A \times \bar{q}$ is about \$130 per sow. That is, the alternative policy could cover about 1.45 million sows or about 19% of the sows in North America. This simple alternative policy would allow Prop 12 standards to apply to about three times as many sows as does the Prop 12 implementation regulations.

The alternative policy provides more hogs the opportunity to experience Prop 12 regulations for the same cost. The alternative policy is more cost-effective than Prop 12 because it avoids adding costs downstream from farrowing operations. California pork consumers buy and eat the same pork as everyone else under the alternative policy, and the costs of improving animal welfare are borne by the general group of California taxpayers instead of just by pork consumers.[15]

[14] R = \$188 million, N = 7.6 million sows, $\bar{q}$ is 3.5376 cwt. of pork per sow, $\underline{\sigma}$ is \$2.49 per cwt., and $\overline{\sigma}$ is \$4.35 per cwt.

[15] An equity argument in favor of the alternative policy is that a ballot proposition is due to the actions of voters generally, and therefore the costs of implementing it should be shared widely. Another consideration is that under Prop 12, Californians know that the covered pork products they consume are from the progeny of hogs confined with at least 24 square feet of space. They would not have this assurance under the alternative policy. Thus, if some Californians care specifically about attributes of the pork they eat and not the welfare of North American sows more generally, they would not view the two policies as equivalent.

4.4. Conclusions

Local jurisdictions have increasingly imposed regulations on agricultural production processes within the jurisdiction to address issues associated with pollution, animal welfare, and farm-worker health and well-being. Several papers have studied the impacts of such regulations, with the work summarized by Sumner (2017). These regulations differ considerably in their impacts from those that restrict farm production practices for products sold within a local jurisdiction. The first type creates heterogeneous production costs and alters the comparative advantage of different production regions but generally does not affect downstream operations. This paper explores the economic implications of the latter group of regulations, with specific application to the impact of California Proposition 12 on the North American pork supply chain.

Key innovations of the model are allowing heterogeneity in the costs of farms to meet the mandate and incorporating that a mandate in many cases will only apply to a portion of the output of the live animal. The model incorporates capital conversion for compliance at farms and variable production proportions between covered and non-covered pork in processing farm raw products into finished consumer products. The model shows how these aspects interact and drive substantial price and quantity adjustments along vertically linked markets and across geographically different markets.

Simulations show that, despite significant industry opposition to Prop 12, its mandates do not impose much negative total effect on hog producers in North America. Most firms that elect to comply with Prop 12's mandates will increase profits, and losses to non-compliers are slight. Prop 12 causes moderately higher prices in California for covered pork products and generates a consumer welfare loss of about $188 million annually.

Prop 12 will not make stall housing operations adopt California's standards. A substantial percentage of pork products already come from breeding pigs confined in group housing operations. These pork products will be diverted for the California market under Prop 12. Because California's standards are stricter than typical group housing, breeding pigs confined in converting operations will have slightly more space than before.

Prop 12 and, more generally, the regulations on products sold in local jurisdictions represent only one policy instrument to improve welfare for farm animals. To illustrate this point, I considered a simple alternative policy under which the California government would raise a general fund to directly subsidize farms that convert their housing practices. I showed that, for the same cost to California, this alternative policy could incentivize conversion of about three times as much sow housing to compliance with Prop 12 regulations as Prop 12 itself will achieve if it becomes fully implemented. This example illustrates that Prop 12 and, more broadly, regulations imposed at the point of purchase are likely not efficient ways to influence conventional farming practices.

Appendix 4.A. Robustness of Simulation Results by Different Specification of the Derived Supply and Demand Functions

The per-unit marketing margins of the two products, c_C and c_N are the parameters of the derived supply and demand functions. The two parameters were calibrated, based on the difference between the average retail price and the average farm price, which is $c_C = P_{r,C} - P_f$ and $c_N = P_{r,N} - P_f$ where $P_{r,C}$ is the retail price of uncooked pork cuts, $P_{r,N}$ is that of non-covered pork, and P_f is the farm price. This approach assumes that the net price of each product after excluding its marketing margin is identical between the two products, which implies $P_{r,C} - c_C = P_{r,N} - c_N$.

To check whether this assumption substantially affects simulation results, a sensitivity analysis was conducted given three different values (0.95, 1.00, and 1.05) of the ratio between the two net prices, which is $\psi = (P_{r,C} - c_C)/(P_{r,N} - c_N)$. The following table shows that simulation results are largely robust to the choices under consideration.

Table 4.A.1. Simulated Market Outcomes under Proposition 12 by Different Specification of the Derived Supply and Demand Functions

Variable	Unit	Values of ψ		
		0.95	1.00	1.05
Prices				
Average price, all slaughter hogs	$/cwt	79.20	79.20	79.20
Price, hogs for California pork	$/cwt	81.94	81.94	81.93
Price, hogs for non-California pork	$/cwt	79.00	78.99	78.99
Average retail price, uncooked cuts of pork	$/lb	3.32	3.32	3.32
Retail price, California uncooked cuts	$/lb	3.53	3.53	3.53
Retail price, non-California uncooked cuts	$/lb	3.29	3.29	3.29
Retail price, non-covered pork	$/lb	3.79	3.79	3.79
Quantities				
Retail weight, hogs slaughtered	million cwt	232.7	232.7	232.6
for California[a]	million cwt	16.4	16.4	16.4
for non-California	million cwt	166.8	166.7	166.7
for net export[b]	million cwt	49.5	49.5	49.5
Share of hogs for the California market	%	7.1	7.1	7.1
Uncooked cuts share in compliant hog carcass	%	66.6	66.6	66.6
Retail uncooked pork cuts	billion lb	15.37	15.37	15.37
California retail uncooked pork cuts	billion lb	1.09	1.09	1.09
Non-California retail uncooked pork cuts	billion lb	9.56	9.56	9.56
Net export, uncooked pork cuts	billion lb	4.72	4.72	4.72
Retail non-covered pork	billion lb	7.9	7.9	7.9
California non-covered pork	billion lb	0.85	0.85	0.85
Non-California non-covered pork	billion lb	6.81	6.81	6.81
Net export, non-covered pork	billion lb	0.23	0.23	0.23
Changes in Producer and Consumer Welfare				
Net gain, total	$ million	-44.1	-44.6	-45.1
Net gain, converters	$ million	0.24	0.21	0.17
Net gain, non-converters	$ million	-44.3	-44.8	-45.2
Consumer surplus change, total, CA	$ million	-188.2	-188.1	-188.1
Covered pork	$ million	-257.5	-257.6	-257.6
Non-covered pork	$ million	69.3	69.4	69.5
Consumer surplus change, total, non-CA	$ million	17.7	18.0	18.2
Covered pork	$ million	63.6	63.4	63.2
Non-covered pork	$ million	-45.9	-45.5	-45.0
Consumer surplus change, total, all	$ million	-170.5	-170.2	-169.9
Covered pork	$ million	-193.9	-194.1	-194.4
Non-covered pork	$ million	23.4	23.9	24.5

Notes: I use million cwt for hog production quantity and billion pounds for retail pork quantity in units. The term ψ is the ratio between (i) the net price of covered pork after excluding its marketing margin and (ii) the net price of non-covered pork. The base case is $\psi = 1.00$.

a. The retail weight of hogs produced under California standards.

b. I assume that the net export quantity is fixed and that net exports come from non-compliant hogs.

Appendix 4.B. Derivation of Relations to Calibrate the Parameters of the CET Production Possibility Frontier

The goal is to express the parameter α as a function of other parameters and variables evaluated at the observed market outcomes. The derivation starts with one of the first order conditions of the profit maximization problem of the intermediaries (which is equation (3.B.7) in Appendix 3.B):

$$q_{r,N} = \left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{1}{\rho-1}} q_{r,C}.$$

The homogeneity among producers yields,

$$Q_{r,N} = \left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{1}{\rho-1}} Q_{r,C}. \qquad (4.B.1)$$

Then,

$$Q_{r,N} = \left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{1}{\rho-1}} Q_{r,C}$$

$$\Leftrightarrow \frac{Q_{r,N}}{Q_{r,C}} = \left(\frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}\right)^{\frac{1}{\rho-1}}$$

$$\Leftrightarrow \left(\frac{Q_{r,N}}{Q_{r,C}}\right)^{\rho-1} = \frac{\alpha}{1-\alpha}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}$$

$$\Leftrightarrow \frac{1-\alpha}{\alpha} = \left(\frac{Q_{r,C}}{Q_{r,N}}\right)^{\rho-1}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}$$

$$\Leftrightarrow \frac{1}{\alpha} = 1 + \left(\frac{Q_{r,C}}{Q_{r,N}}\right)^{\rho-1}\frac{P_{r,N}-c_N}{P_{r,C}-c_C}$$

$$\Leftrightarrow \alpha = \frac{1}{1 + \left(\frac{Q_{r,C}}{Q_{r,N}}\right)^{\rho-1} \frac{P_{r,N} - c_N}{P_{r,C} - c_C}} = \frac{\frac{P_{r,C} - c_C}{\left(Q_{r,C}\right)^{\rho-1}}}{\frac{P_{r,C} - c_C}{\left(Q_{r,C}\right)^{\rho-1}} + \frac{P_{r,N} - c_N}{\left(Q_{r,N}\right)^{\rho-1}}}.$$

Because $\tau = 1/(\rho - 1)$,

$$\alpha = \frac{\frac{P_{r,C} - c_C}{\left(Q_{r,C}\right)^{\frac{1}{\tau}}}}{\frac{P_{r,C} - c_C}{\left(Q_{r,C}\right)^{\frac{1}{\tau}}} + \frac{P_{r,N} - c_N}{\left(Q_{r,N}\right)^{\frac{1}{\tau}}}}. \tag{4.B.2}$$

Given the calibrated α, the scale parameter A can be calibrated, given the CET production possibility frontier:

$$A = \frac{Q_f}{\left(\alpha\left(Q_{r,C}\right)^{\rho} + (1 - \alpha)\left(Q_{r,N}\right)^{\rho}\right)^{\frac{1}{\rho}}}. \tag{4.B.3}$$

Appendix 4.C. Economic Effects of Proposition 12 Using Different Values of the Elasticity of Transformation

Covered and non-covered pork were allowed to be produced under variable proportions. For this purpose, the model allows a constant elasticity of transformation (CET) function. A key parameter of the CET function is the elasticity of transformation, denoted by τ. It was assessed to be 0.5 for simulations to reflect an intermediate-run horizon.

Because of uncertainty about τ, a sensitivity analysis was conducted given different values of the elasticity of transformation, 0.2, 0.5, and 1.0. Table 4.C.1 reports the simulated prices, quantities, and producer surplus changes, and consumer surplus changes by different values of the elasticity of transformation. The simulation results are robust to different values of the elasticity of transformation.

Table 4.C.1. Simulated Market Outcomes under Proposition 12 by Different Values of the Elasticity of Transformation

Variable	Unit	Values of τ		
		0.2	0.5	1.0
Prices				
Average price, all slaughter hogs	$/cwt	79.20	79.20	79.20
Price, hogs for California pork	$/cwt	81.94	81.94	81.93
Price, hogs for non-California pork	$/cwt	78.99	78.99	79.00
Average retail price, uncooked cuts of pork	$/lb	3.32	3.32	3.32
Retail price, California uncooked cuts	$/lb	3.53	3.53	3.53
Retail price, non-California uncooked cuts	$/lb	3.29	3.29	3.30
Retail price, non-covered pork	$/lb	3.80	3.79	3.79
Quantities				
Retail weight, hogs slaughtered	million cwt	232.6	232.7	232.6
for California[a]	million cwt	16.5	16.4	16.3
for non-California	million cwt	166.6	166.7	166.9
for net export[b]	million cwt	49.5	49.5	49.5
Share of hogs for the California market	%	7.1	7.1	7.0
Uncooked cuts share in compliant hog carcass	%	66.3	66.6	67.2
Retail uncooked pork cuts	billion lb	15.37	15.37	15.36
California retail uncooked pork cuts	billion lb	1.10	1.09	1.09
Non-California retail uncooked pork cuts	billion lb	9.56	9.56	9.55
Net export, uncooked pork cuts	billion lb	4.72	4.72	4.72
Retail non-covered pork	billion lb	7.9	7.9	7.9
California non-covered pork	billion lb	0.85	0.85	0.86
Non-California non-covered pork	billion lb	6.80	6.81	6.81
Net export, non-covered pork	billion lb	0.23	0.23	0.23
Changes in Producer and Consumer Welfare				
Net gain, total	$ million	-45.4	-44.6	-43.9
Net gain, converters	$ million	0.17	0.21	0.23
Net gain, non-converters	$ million	-45.6	-44.8	-44.1
Consumer surplus change, total, CA	$ million	-189.3	-188.1	-186.8
Covered pork	$ million	-255.7	-257.6	-257.7
Non-covered pork	$ million	66.5	69.4	70.9
Consumer surplus change, total, non-CA	$ million	15.8	18.0	19.2
Covered pork	$ million	86.5	63.4	49.3
Non-covered pork	$ million	-70.7	-45.5	-30.1
Consumer surplus change, total, all	$ million	-173.5	-170.2	-167.6
Covered pork	$ million	-169.2	-194.1	-208.4
Non-covered pork	$ million	-4.2	23.9	40.8

Notes: I use million cwt for hog production quantity and billion pounds for retail pork quantity in units. The term τ is the elasticity of transformation in the production of the two products (covered pork and non-covered pork). The base case is $\tau = 0.5$.

a. The retail weight of hogs produced under California standards.

b. I assume that the net export quantity is fixed and that net exports come from non-compliant hogs.

Appendix 4.D. Detailed Description of Parameter Specification

This appendix provides detailed explanations on the methods for specifying the model parameter estimates that reflect California's Prop 12 regulations on pork sold in California and the North American pork supply chain. All parameters and data are listed in Tables 4.D.1 and 4.D.2 along with values and sources.

Parameters of Primary Supply and Demand Functions

The parameters of primary supply and demand functions were calibrated around the 2018 values in the North American hog and pork markets. North America includes Canada and the United States. The price elasticity of supply, -1.8, was adopted from Lemieux and Wohlgenant (1989), which has been used in other papers in the literature (Wohlgenant 1993; Saitone, Sexton, and Sumner 2015).

To complete the calibration of the primary supply function, the farm price and the quantity of hogs were needed. The farm price came from the 2018 net farm value in "Meat Price Spreads" reported by USDA ERS (2021b). The calculation started with the total number of hogs slaughtered in Canada and the United States, about 145 million hogs (Agriculture and Agri-Food Canada 2019; USDA NASS 2020). Converting the number of hogs to the retail weight generated 233 million pounds, based on the conversion factor, 160.8 pounds per hog, which is taken from data supplied by the National Pork Board (Pork Checkoff 2017).

Parameterization of the retail demand functions used the fact that the aggregate demand for all pork is the horizontal sum of the two product demands. Suppose the direct demand function of aggregate pork in North America as

$$Q_{r,T} = a_T - b_T P_{r,T}, \tag{4.D.1}$$

$$Q_{r,T} = Q_{r,C} + Q_{r,N}, \tag{4.D.2}$$

$$P_{r,T} = \mu P_{r,C} + (1 - \mu)P_{r,N}. \tag{4.D.3}$$

A subscript T denotes total demand, and a subscript r denotes retail relationships. Subscript C denotes uncooked cuts of pork, and subscript N denotes non-covered pork. The parameter μ is the share of covered pork in all pork. The variable, $P_{r,T}$, is the retail price of all pork, defined as a quantity weighted average of the two products that comprise all pork. As noted earlier, a linear form for the demand functions is used:

$$Q_{r,C} = a_c - b_{cc}P_{r,C} + h_{cn}P_{r,N}, \tag{4.D.4}$$

$$Q_{r,N} = a_n - b_{nn}P_{r,N} + h_{nc}P_{r,C}. \tag{4.D.5}$$

The relations from (4.D.1) to (4.D.5) imply the following relations:

$$h_{cn} = b_T\mu + b_{cc}, \tag{4.D.6}$$

$$h_{nc} = b_T(1 - \mu) + b_{nn}. \tag{4.D.7}$$

The two relations, (4.D.6) and (4.D.7), imply that the cross-price coefficients can be estimated given the own-price coefficients and the share of uncooked cuts of pork.

The own-price coefficients were estimated given the price elasticity of demand for all pork of -0.68 from Okrent and Alston (2011). Compared to the demand for all pork, the demands for the two sub-categories of pork products will be more price elastic because consumers are able to substitute between the two categories in response to changes in their relative prices. A review of the relevant literature suggested values of -0.9 for uncooked cuts of pork and -1.1 for non-covered pork in own-price elasticity. See the section, Model Calibration, in the main text for more discussion on the choice of demand elasticities.

The calibration needs the retail prices and quantities of uncooked cuts of pork and non-covered pork. The retail revenue and quantity data by detailed categories of pork products were obtained from the National Pork Board and originally came from Nielsen (2019). Based on the specification of uncooked cuts of pork defined by Prop 12, the quantities of small categories were aggregated into uncooked cuts of pork and non-covered pork. The corresponding retail prices were calculated by dividing the revenue by the quantity. The retail prices are $3.30 per pound for uncooked cuts of pork and $3.79 per pound for non-covered pork.

North American Pork Trade Data

Part of the North American hog production goes outside North America, and I model that the net export quantity is fixed, as explained in the section of model calibration in the paper. I obtained the U.S. pork trade data from USITC DataWeb, provided by U.S. International Trade Commission (USITC 2022). The Canada data came from *Canadian International Merchandise Trade Web Application*, provided by Statistics Canada (Statistics Canada 2022).

I obtained the pork trade codes (HS-10 level) from USDA ERS (2022). The first six digits of HS codes are common between the two countries, but Canada uses different HS-8 level codes for exports and HS-10 level codes for imports. I used the corresponding HS codes of Canada based on the HS code description. I allocated HS codes starting 0203 and 0210 (for pork meat) into the group of covered pork and those starting 1601 and 1602 (for processed pork products, products with pork and other ingredients) into the group of non-covered pork, given the definition that covered pork is any uncooked cut of pork comprised of pork meat except for seasoning, curing, coloring, flavoring, preservatives, and similar meat additives. Table 4.D.3 reports HS codes by pork products and countries.

The trade data sources reported the quantity in terms of kilograms of product weight. I used the conversion factors that convert the kilograms of product weight into pounds of hog carcass-weight equivalent, reported by USDA ERS (2022). Next, I converted the pounds of carcass-weight equivalent into pounds of retail weight equivalent, given 215 pounds of carcass weight per hog and 160.8 pounds of retail weight per hog.

Parameters of Derived Supply and Demand Functions

Two sets of parameters characterize the derived supply and demand functions: (i) the processing and marketing costs of covered pork, c_C, and those of non-covered pork, c_N, and (ii) the parameters of the CET production possibility frontier, which are ρ, α, and A.

The parameter, c_C, came from the difference between the 2018 average retail price for uncooked cuts of pork and the 2018 average farm price for the retail weight of market hogs. A similar procedure was used to calibrate the processing and marketing cost of non-covered pork, c_N. In terms of the parameters of the CET frontier, the first step was to assess the elasticity of transformation, τ, to be 0.5. The next step was to obtain the value of ρ based on the relationship, $\tau = 1/(\rho - 1)$. The calibration of the other parameters, ρ, α, and A, is explained in Appendix 7.C above.

Farm Costs of Compliance with California Regulations

To assess farm costs of compliance, I used the 2020 farrow-to-wean budget constructed by AgManager.info, Department of Agricultural Economics, Kansas State University (Tonsor and Reid 2020). In this data source, most information about fixed and variable costs derived from Hogs farrow-weanling production costs and returns, reported by USDA-ERS (2021a). I also considered productivity information, including declarations from producers included in the Petitioners Complaint in UNITED STATES DISTRICT COURT SOUTHERN DISTRICT OF

CALFIORNIA CASE (*National Pork Producers Council, et al. v. Ross*, No. 20-55631), and Table 4.D.4 summarizes the declarations.

The data source reflects conventional housing (typical stall housing operations). The hog production for the California market under Prop 12 will come solely from group housing farms because they have a cost advantage in converting over conventional farms. Hence, I first adjusted the production costs to represent typical group housing. Second, I assessed the incremental costs to convert typical group housing to California standards.

<u>The increase in capital recovery and related fixed costs</u>: The data source indicates that the capital costs are $196.40 per sow per year in conventional housing. A common gestation stall allows about 14 square feet per sow (McGlone 2013). According to conversations with industry personnel, the typical group housing space allowance is about 20 square feet per sow of usable space on average. After the conversion from stall housing to group housing, the capital costs must be spread over about 43% (=6/14) fewer sows. Thus, I adjusted the capital costs from 196.40 to $280.57 per sow per year (a 43% increase) to represent typical group housing.

I used cost estimates per pig basis in simulations. The Kansas State estimate of pigs per sow per year is 23.9, reflecting conventional housing. In group housing where sows are mixed, sows compete for social dominance and feed, which causes increases in injuries and mortality and then negatively affects fertility (Supakorn et al. 2019). I adjusted the number of pigs from 23.9 to 22.76 pigs per sow per year (a 5% decrease, adjusted by dividing 23.9 by 1.05) to reflect typical group housing based on my surveys and interviews. Thus, the capital cost per pig was calculated to be $12.33 per pig per year (=$280.57 per sow per year /22.76 pigs per sow per year) in typical group housing.

The Prop 12 minimum space requirement is 24 square feet per sow of usable floor space. Again, the capital costs must be spread over about 20% (=4/20) fewer sows. Thus, I adjusted the capital costs per sow per year from $280.57 to $336.68 (a 20% increase) to reflect California standards.

Also, I adjusted the pigs per sow per year downward to reflect California standards. A sow often needs to be confined in a small cage separately from other sows because of farrowing, lactating, and other health issues, and Prop 12 allows exceptions as follows: (1) Breeding pigs may be confined for farrowing at most five days prior to breeding pigs' expected date of giving birth and while nursing piglets, and; (2) Confinement for animal husbandry treatment is allowed no more than six hours in any 24-hour period and no more than 24 hours total in any 30-day period. However, breeding pigs are often moved to farrowing crates earlier than five days prior to the expected birth date because of the condition of the breeding pigs. Also, the period around mating is critical for sow reproduction, and prolonged stress can negatively affect sow reproduction during that period (Turner et al. 2005; Knox et al. 2014). Mixing breeding pigs immediately after weaning can cause higher levels of stress than mixing them after insemination (Rault et al. 2014). Based on conversations with farms and other industry personnel, I adjusted the pigs per sow per year to 22.23 (an additional 2.5% decrease, adjusted by dividing 23.9 by 1.075) to reflect California standards, compared to typical group housing. Thus, the capital cost per pig was calculated to be $15.14 per pig (=$336.68 per sow per year/22.23 pigs per sow per year) in California standards. I obtained the incremental capital cost of $3 per pig (the rounded value of $15.14 - $12.33 per pig) through the cost difference between typical group housing and California standards.

The increase in variable costs: The data source indicates that the total variable cost is $667.65 per sow per year in conventional housing. As described earlier, compared to conventional housing, aggressive behaviors among sows in group housing raise sow injuries/mortality and reduce feeding and breeding efficiency, which raises variable costs. The data source indicates that, in the variable costs, the cost of feed and vet medicine/drugs is $401.93 per sow per year in conventional housing. Based on my surveys and interviews, I adopted a 5% increase in the costs of feed and vet medicine/drugs ($20.10 per sow per year) to reflect typical group housing compared to conventional housing. I assessed no change in labor costs, semen cost, and genetic fees, although more labor and semen/genetic service are expected per litter in group housing, because I also expect fewer litters per sow per year in group housing due to less breeding efficiency compared to conventional housing. The Kansas Stata data use 8% sow mortality. I assessed the sow mortality to rise by 5% (i.e., 8.4% sow mortality) in typical group housing, and the costs of replacement females rise by $0.79 per sow per year (=the replacement cost of $198.06 per sow * 0.004) to compensate for the incremental sow mortality. Thus, the total variable cost was calculated to be $688.54 per sow per year (=$667.65 + $20.10 + $0.79), or $30.25 per pig (=$688.54 per sow per year/22.76 pigs per sow per year) in typical group housing.

The conversion from typical group housing to California standards also affects variable costs. As described earlier, Prop 12 restricts typical practices during the breeding, farrowing, and weaning stages. Based on my surveys and interviews, I adopted another 5% increase in the costs of feed and vet medicine/drugs ($20.10 per sow per year) by California standards. Similarly, I assessed no change in labor costs, semen costs, and genetic fees in California standards because the adoption of California standards is expected to raise those costs per litter but reduce litters per sow per year, which cancels out each other. I assessed the sow mortality to rise additionally by 2.5% additionally (i.e., 8.6% sow mortality), and the costs of replacement females rise by $0.40 per sow per year (=the replacement cost of $198.06 per sow * 0.002) to compensate for the higher sow mortality in California standards, compared to typical group housing. Thus, the total variable cost was calculated to be $709.03 per sow per year (=$688.54 + $20.10 + $0.40), or $31.89 per pig (=$709.03 per sow per year/22.23 pigs per sow per year).

I obtained the incremental variable cost of $2 per pig (the rounded value of $31.89 - $30.25 per pig) through the cost difference between California standards and typical group housing. Finally, putting the incremental fixed and variable costs implies $5 per pig (=$3 + $2 per pig) as the total incremental costs for Prop 12 compliance.

The distribution of farm compliance costs: A uniform distribution was characterized to consider how farm compliance costs are likely to vary across farms considering becoming Prop 12 compliant. The calibration of the distribution parameters is explained in the main text of the paper (the section, Model Calibration).

Table 4.D.1. Parameter Definitions, Base-Case Values, Specifications, and Sources

Symbol	Definition	Value	Source
a	Intercept of the supply function of non-compliant live hogs ($/cwt, retail weight)	35.2	Calibrated value based on the 2018 values of market outcomes
b	Slope of the supply function of non-compliant live hogs ($/million cwt, retail weight)	0.19	Calibrated value based on the 2018 values of market outcomes
ν	Incremental operating costs at compliant farms by Prop 12 ($/cwt, retail weight equivalent)	1.24	My assessment based on surveys from farms
Δc_C^p	Unit costs of processing for compliant hogs ($/cwt, retail weight)	9.33	My assessment based on surveys from market participants
Δc_C^m	Unit costs of marketing for compliant uncooked pork ($/cwt, retail weight)	5.00	My assessment based on surveys from market participants
c_C	Unit costs of marketing for non-compliant uncooked pork ($/cwt, retail weight)	250.8	Calibrated value based on the 2018 values of market outcomes
c_N	Unit costs of marketing for cooked pork ($/cwt, retail weight)	299.8	Calibrated value based on the 2018 values of market outcomes
γ	Intercept of demand function of uncooked pork at retail ($/cwt, retail weight)	831.5	Calibrated value based on the 2018 values of market outcomes
β_{cc}	Slope of own price in demand function of uncooked pork at retail ($/million cwt, retail weight)	3.79	Calibrated value based on the 2018 values of market outcomes
β_{cn}	Slope of cooked pork price in demand function of uncooked pork at retail ($/million cwt, retail weight)	1.26	Calibrated value based on the 2018 values of market outcomes
θ	Intercept of demand function of cooked pork at retail ($/cwt, retail weight)	913.6	Calibrated value based on the 2018 values of market outcomes
η_{nn}	Slope of own price in demand function of cooked pork at retail ($/million cwt, retail weight)	4.97	Calibrated value based on the 2018 values of market outcomes
η_{nc}	Slope of uncooked pork price in demand function of cooked pork at retail ($/million cwt, retail weight)	1.44	Calibrated value based on the 2018 values of market outcomes
δ	Share of the CA quantity consumed in the North America quantity consumed of uncooked pork at retail	0.109	Calibrated value based on the 2018 population

Table 4.D.2. Elasticities and the 2018 Market Data Used to Calibrate Parameters

Definition	Value	Source
Price elasticity of live hog supply	1.8	Lemieux and Wohlgenant (1989)
Price elasticity of aggregate pork demand at retail	-0.68	Okrent and Alston (2011)
Own price elasticity of uncooked pork at retail	-0.9	My assessment of substitution between cooked and uncooked products
Own price elasticity of cooked pork at retail	-1.1	My assessment of substitution between cooked and uncooked products
The 2018 market price of live hogs ($/cwt, retail weight equivalent)	79.2	USDA-ERS (2021b)
The 2018 number of hogs slaughtered in the U.S. (million heads)	124.4	USDA-NASS (2020)
The 2018 number of hogs slaughtered in Canada (million heads)	20.6	Agricultural and Agri-Food Canada (2019)
Retail pork weight per finished hog (lbs. per head)	160.8	Pork Checkoff (2017).
The 2018 average price of uncooked pork products in the U.S. retail market ($/cwt, retail weight)	330	Provided to authors by NPB based on data in Nielsen (2019)
The 2018 average price of cooked pork products in the U.S. retail market ($/cwt, retail weight)	379	Provided to authors by NPB based on data in Nielsen (2019)
The 2018 quantity net-exported of uncooked pork from North America to the rest of the world (million cwt)	47.2	USITC (2022); Statistics Canada (2022)
The 2018 quantity net-exported of cooked pork from North America to the rest of the world (million cwt)	2.33	USITC (2022); Statistics Canada (2022)
The 2018 U.S. population (million)	327.2	USCB (2019b)
The 2018 Canada population (million)	37.1	Statistics Canada (2019)
The 2018 California population (million)	39.6	USCB (2019a)

Table 4.D.3. HS Codes, Covered and Non-Covered Pork, Canada, and the United States

Panel A. HS Codes, Covered and Non-Covered Pork, the United States		
	Export	Import
Covered pork	0203.11.0000, 0203.12.1000, 0203.12.9000, 0203.19.2000, 0203.19.4000, 0203.21.0000, 0203.22.1000, 0203.22.9000, 0203.29.2000, 0203.29.4000, 0210.11.0000, 0210.12.0020, 0210.12.0040, 0210.19.0000	0203.11.0000, 0203.12.1010, 0203.12.1020, 0203.12.9010, 0203.12.9020, 0203.19.2010, 0203.19.2090, 0203.19.4010, 0203.19.4090, 0203.22.1000, 0203.22.9000, 0203.29.2000, 0203.29.4000, 0210.11.0010, 0210.11.0020, 0210.12.0020, 0210.12.0040, 0210.19.0010, 0210.19.0090
Non-covered pork	1601.00.0090, 1602.10.0002, 1602.41.2000, 1602.41.9000, 1602.42.2000, 1602.42.4000, 1602.49.2000, 1602.49.4000, 1602.49.7000, 1602.90.0002	1601.00.2010, 1601.00.2090, 1601.00.6080, 1602.20.4000, 1602.41.2020, 1602.41.2040, 1602.41.9000, 1602.42.2020, 1602.42.2040, 1602.42.4000, 1602.49.1000, 1602.49.2000, 1602.49.4000, 1602.49.6000, 1602.90.9160, 1602.90.9180
Panel B. HS Codes, Covered and Non-Covered Pork, Canada		
	Export	Import
Covered pork	0203.11.00, 0203.12.10, 0203.12.20, 0203.19.10, 0203.19.91, 0203.19.99, 0203.21.00, 0203.22.00, 0203.29.00, 0210.11.10, 0210.11.20, 0210.12.10, 0210.12.90, 0210.19.10, 0210.19.90	0203.12.0000, 0203.19.0010, 0203.19.0020, 0203.19.0091, 0203.19.0099, 0203.21.0000, 0203.22.0000, 0203.29.0010, 0203.29.0020, 0203.29.0090, 0210.11.0000, 0210.12.0000, 0210.19.0000
Non-covered pork	1601.00.00, 1602.10.00, 1602.20.00, 1602.41.10, 1602.41.90, 1602.42.00, 1602.49.00	1601.00.9010, 1601.00.9020, 1601.00.9080, 1601.00.9090, 1602.10.9000, 1602.41.1000, 1602.41.9000, 1602.42.1000, 1602.42.9000, 1602.49.1010, 1602.49.1020, 1602.49.9000, 1602.90.1000, 1602.90.9100, 1602.90.9900

Notes. Canada uses HS-8 for exports.

Table 4.D.4. Declarations from Farmers about Proposition 12 in the Appendices of *National Pork Producers Council v. Ross*, No. 20-55631

Ex	State	Size of sows/hogs	Current housing	Conversion cost	Labor cost	Injuries, mortality	Productivity	Other costs
C	WI	3,000 sows, 72,000 weaned pigs	Farrow-to-wean, stalls (15 square feet per sow)	$200,000 costs and 10-15% fewer sows; Or a higher construction costs and no sow reduction	Higher in pens	Three times more injuries in pens	11% higher litter size in stalls than pens	
D	MN	10,000 sows, 320,000 hogs per year	Farrow-to-finish, both stalls (14 square feet per sow) and pens (21 or 24 square feet per sow),		20% higher in pens (more labor, more skills)	More injuries in pens	Lower conception rate in pens	More costs for gilts, new feeding system in pens
E	IL	10,000 sows, 225,000 hogs per year	Farrow-to-finish, stalls (14 square feet per sow)	Costs of rebuilding and re-equipping and 33% fewer sows	Higher in pens (higher risk, new employee protocols)	More injuries and higher mortality in pens	Fewer piglets per litter in pens; less litters per year in pens	More costs for gilts, new feeding system, audits etc. of compliance
F	MO	1,300 sows, 30,000 hogs per year	Farrow-to-finish, pens (15 square feet per sow)	Very high construction cost	Higher in pens	More injuries in pens	Fewer litters per year, less breeding efficiency in pens	

G	UT	2,000 sows, 600 sucklings (weigh 16-25 pounds) per week	Farrow-to-feed, stalls (14 square feet per sow)	$500,000 ($400,000 for new barns, $100,000 for land)	Much higher in pens	More injuries, higher mortality in pens	Much lower conception rate	Harder manure management, additional equipment, higher costs of temperature control in winter in pens
H	IA	110 sows, 1,500-2,000 hogs per year	Farrow-to-finish, stalls (no space information)	High construction costs		More injuries, higher mortality in pens	Lower conception rate in pens	Higher medical costs, less feed efficiency, harder to keep identification, costs of management education, higher costs of temperature control in winter in pens
I	MO	600 sows, 13,500 hogs per year	Farrow-to-finish, stalls (16 square feet per sow)	Very high costs of remodeling and fewer sows	Higher in pens (lower worker safety, harder to manage)	More injuries, higher mortality in pens	Fewer piglets per sow in pens (safer for the inseminatio n)	More medical cares, less feed efficiency in pens, new feeding and watering systems
J	OH	1,600 sows, 35,000-36,000 hogs per year	Farrow-to-finish, both stalls and pens (no space information)	Fewer sows using the current facility; or significant cost of new construction	Higher in pens	More injuries in pens	Lower conception rate in pens	Less feed efficiency in pens, new feeding system

K	IL	3,200 sows, 90,000-100,000 hogs per year	Farrow-to-finish, both stalls (no space information) and pens (19 square feet per sow)	Very high costs of remodeling	Higher in pens	More injuries, higher mortality in pens	Lower conception rate in pens	Harder to provide medical cares, less feed efficiency in pens
L	MO	2,500 sows, 52,000 pigs (2/3 are piglets, 1/3 hogs)	Farrow-to-wean & farrow-to-finish, both stalls (14 square feet per sow) and pens (16 square feet per sow)		Higher in pens (more labor and training)	More injuries, an increase in mortality rate (2% in stalls to 10% in pens)	Lower conception rate in pens	New feeding equipment
M	MN	10,000 sows, 250,000 hogs per year	Farrow-to-finish, stalls (15-16 square feet per sow)	Very high construction costs	Higher in pens (harder to manage, lower worker safety)	Higher mortality in pens	Much lower conception rate in pens	
N	MT	470 sows, 13,500 hogs per year	Farrow-to-finish, stalls (no space information)	20% fewer sows; Or, very high costs of new building		More injuries in pens, 20% more replacement gilts to replace injured sows		

Source: Appendices, *National Pork Producers Council v. Ross*, No. 20-55631. Exhibits C through N in Appendix to December 5, 2019 Complaint in Federal District court. Pages 260 to 340.

Appendix 4.E. Economic Effects of Proposition 12 When Some Farms Cannot Participate in the California Market due to Contractual Reasons

In equation (3.22) in Chapter 3, I assume that farms with lower conversion costs participate in the California market. However, I acknowledge that some farms, even with low conversion costs, cannot supply to the California market due to contractual reasons. Hence, my model may underestimate the impact of Prop 12 on the North American hog market.

To illustrate, let us consider that half of the farms with the lowest conversion costs cannot supply to the California market. For simplicity, assume that those farms are evenly distributed in the uniform distribution of conversion costs specified in Chapter 3. This new specification implies that the range from $2 to $5 per pig (or $1.24 to $3.11 per cwt, retail weight equivalent) of conversion costs now covers the first 15% of the North American hog production, instead of 30% in the baseline specification. Given this new specification, Prop 12 raises the hog price for the California market by 4.0% (or $3.14 per cwt), which is higher than the baseline hog price increase of 3.5% (or $2.74 per cwt).

Table 4.E.1. Impacts of Proposition 12 When Some Farms Cannot Participate in the California Market due to Contractual Reasons

Variable	Unit	Base	Prop 12	Percent Change
Prices				
Average price, all slaughter hogs	$/cwt	79.20	79.20	0.003
Price, hogs for California pork	$/cwt	79.20	82.34	4.0
Price, hogs for non-California pork	$/cwt	79.20	78.97	-0.3
Average retail price, uncooked cuts of pork	$/lb	3.30	3.32	0.6
Retail price, California uncooked cuts	$/lb	3.30	3.54	7.1
Retail price, non-California uncooked cuts	$/lb	3.30	3.29	-0.2
Retail price, non-covered pork	$/lb	3.79	3.80	0.1
Quantities				
Retail weight equivalent, hog production	million cwt	233.1	232.7	-0.2
for California	million cwt	17.6	16.4[a]	-7.1
for non-California	million cwt	166.0	166.8	0.5
for net export	million cwt	49.5	49.5[b]	0
Share of hogs for the California market	%	7.6	7.0	-6.9
Uncooked cuts share in compliant hog carcass	%	66.2	66.7	0.8
Retail uncooked pork cuts	billion lb	15.42	15.37	-0.4
California retail uncooked pork cuts	billion lb	1.17	1.09	-6.4
Non-California retail uncooked pork cuts	billion lb	9.54	9.56	0.2
Net export, uncooked pork cuts	billion lb	4.72	4.72	0
Retail non-covered pork	billion lb	7.66	7.90	0.1
California non-covered pork	billion lb	0.84	0.86	2.4
Non-California non-covered pork	billion lb	6.82	6.81	-0.2
Net export, non-covered pork	billion lb	0.23	0.23	0
Changes in Producer and Consumer Welfare				
Net gain, total	$ million	-47.9		
Net gain, converters	$ million	3.178		
Net gain, non-converters	$ million	-51.0		
Consumer surplus change, total, CA	$ million	-192.7		
Covered pork	$ million	-263.9		
Non-covered pork	$ million	71.3		
Consumer surplus change, total, non-CA	$ million	21.0		
Covered pork	$ million	67.9		
Non-covered pork	$ million	-47.0		
Consumer surplus change, total, all	$ million	-171.7		
Covered pork	$ million	-196.0		
Non-covered pork	$ million	24.3		

Notes: Prop 12 requires that uncooked cuts of pork sold in California must come from compliant hogs. Prop 12 does not regulate other pork products, which are denoted as "non-covered pork" in this table. I use million cwt for hog production quantity and billion pounds for retail pork quantity in units.

a. The retail weight of hogs produced under California standards.

b. I assume that the net export quantity is fixed and that net exports come from non-compliant hogs.

References

Agriculture and Agri-Food Canada. 2019. *Number of Hogs Slaughtered in Federally Inspected Establishments in Canada. Government of Canada*. Available at: https://agriculture.canada.ca/en/market-information-system/rp/index-eng.cfm?action=gR&r=105&signature=7FF3E3B4BB0CE7917D8E69759DC75C35&pdctc=&pTpl=1#wb-cont. Accessed July 16, 2022.

Buhr, B. 2005. "U.S. Pork, Beef, and Chicken Sector Economic Simulation Model with International Trade and Probability-Based Sensitivity Analysis." Report prepared for the National Pork Board.

Hailu, G., R. J. Vyn, and Y. Ma. 2014. "The Demand for Pork Products in Canada: Discount Promotions and Cannibalization." *Agribusiness* 30(4): 470-492.

Lemieux, C. M., and M. K. Wohlgenant. 1989. "Ex Ante" Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *American Journal of Agricultural Economics* 71(4): 903-914.

Knox, R. V., S. N. Breen, K. L. Willenburg, S. Roth, G. M. Miller, K. M. Ruggiero, and L. Rodriguez-Zas. 2004. "Effects of Housing System and Boar Exposure on Estrus Expression in Weaned Sows." *Journal of Animal Science* 82(10): 3022-3093.

McGlone, J. 2013. *Gestation Stall Design and Space: Care of Pregnant Sows in Individual Gestation Housing*. National Pork Board. Available at: https://porkcheckoff.org/wp-content/uploads/2021/05/Gestation-Stall-Design-and-Space.pdf. Accessed December 26, 2021.

Milgrom, P. 2004. *Putting Auction Theory to Work.* New York: Cambridge University Press.

Nayga, R. M. Jr, and O. Capps. 1994. "Tests of Weak Separability in Disaggregated Meat Products." *American Journal of Agricultural Economics* 76(4): 800-808.

Nielsen Company. 2019. Nielsen Answers. Available at: https://www.nielsen.com/us/en/client-login/.

Okrent, A., and J. M. Alston. 2011. *Demand for Food in the United States: A Review of the Literature, Evaluation of Previous Estimates and Presentation of New Estimates of Demand*. Berkeley, CA: Giannini Foundation of Agricultural Economics Monograph 48. Available at: http://giannini.ucop.edu/Monographs/48-FoodDemand.pdf.

Pork Checkoff. National Pork Board. 2017. *Typical Market Pig Today*. Available at: https://www.pork.org/facts/stats/consumption-and-expenditures/typical-market-pig-today/. Accessed November 2019.

Rault, J. L., R. S. Morrison, C. F. Hansen, and P. H. Hemsworth. 2014. "Effects of Group Housing after Weaning on Sow Welfare and Sexual Behavior." *Journal of Animal Science* 92(12): 5683-5692.

Saitone, T. L., R. J. Sexton, and D. A. Sumner. 2015. "What Happens When Food Marketers Require Restrictive Farming Practices?" *American Journal of Agricultural Economics* 97(4): 1021-1043.

Statistics Canada. 2019. *Population Estimates on July 1st, by Age and Sex*. Table 17-10-0005-01. Available at: https://doi.org/10.25318/1710000501-eng. Accessed July 16, 2022.

Statistics Canada. 2022. *Canadian International Merchandise Trade Web Application*. Available at: https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021004-eng.htm. Accessed July 26, 2022.

Supakorn, C., G. Moeller, J. D. Stock, A. K. Johnson, and K. J. Stalder. 2019. "A Review of Aetiology and Risk Factors Affecting Sow Mortality." *CAB Reviews* 14(26): 1-9.

Tonsor, G. T., and R. Reid. 2020. *KSU-Swine Farm Management Guide Budgets*. AgManager.info. K-State Department of Agricultural Economics. Available at: https://www.agmanager.info/farm-mgmt-guides/livestock-budgets. Assessed December 26, 2021.

Turner, A. I., P. H. Hemsworth, and A. J. Tilbrook. 2005. "Susceptibility of Reproduction in Female Pigs to Impairment by Stress or Elevation of Cortisol." *Domestic Animal Endocrinology* 29(2): 398-410.

U.S. Census Bureau. 2019a. *QuickFacts: California*. Available at: https://www.census.gov/quickfacts/CA. Accessed July 16, 2022.

U.S. Census Bureau. 2019b. *QuickFacts: United States*. Available at: https://www.census.gov/quickfacts/fact/table/US/IPE120218. Accessed July 16, 2022.

U.S. Department of Agriculture, Economic Research Service. 2021 (USDA ERS 2021a). "Hogs, Farrow-Wean." *Commodity Costs and Returns*. Available at: https://www.ers.usda.gov/webdocs/DataFiles/47913/HogsFarrowWeanlingCostReturn.xlsx?v=252.9. Access December 26, 2021.

U.S. Department of Agriculture Economic Research Service. 2021. (USDA ERS 2021b). *Pork Values and Spreads*. Available at: https://www.ers.usda.gov/data-products/meat-price-spreads/.

U.S. Department of Agriculture Economic Research Service. 2022. (USDA ERS 2022). *Livestock and Meat Trade Codes and Conversion Factors*. Available at: https://www.ers.usda.gov/media/10697/tradecodesconversionfactors_update.xls. Accessed July 26, 2022.

U.S. Department of Agriculture Natural Agricultural Statistics Service. (USDA NASS). 2020. Livestock Slaughter. Available from: https://usda.library.cornell.edu/concern/publications/rx913p88g?locale=en#release-items.

U.S. International Trade Commission. 2022. *USITC DataWeb*. Available at: https://dataweb.usitc.gov/.

Wohlgenant, M. K. 1993. "Distribution of Gains from Research and Promotion in Multi-Stage Production Systems: The Case of the U.S. Beef and Pork Industries." *American Journal of Agricultural Economics* 75: 642-651.

Wohlgenant, M. E., and R. C. Haidacher. 1989. Retail to Farm Linkage for a Complete Demand System of Food Commodities. Washington DC: U.S. Department of Agriculture, Economic Research Service, Technical Bulletin 1775.

Chapter 5. Demand for Carrot Attributes Linked to Farm Production and Processing Practices: Research Background and Survey Data

Chapter 5 provides background used in the following chapters on consumer demand for food attributes linked to farm production and processing practices for carrots.

Chapter 5 introduces related literature in food demand, which is I consider in four subsections. First, I consider the large literature on demand for organic foods, and second, I review the few studies on demand for fresh-cut produce. Third, I review relevant aspects of demand estimation using survey data, and finally, I consider recent research on effects of the COVID-19 pandemic on food demand. Next, I provide an overview of the U.S. fresh carrot market from publicly available data.

Most of Chapter 5 is devoted to explaining the surveys used to collect the data that underlies estimates of buyer willingness to pay for two attributes: organic carrots and fresh-cut (baby) carrots. I conducted simple, web-based surveys of hundreds of thousands of potential carrot buyers. Respondents faced two types of questions used to elicit information about their comparisons of carrot attributes. For the first type of question, respondents were shown a picture of one of four carrot packages product and were asked to choose the most they would pay among several willingness to pay (WTP) intervals. Other respondents in the sample were shown a picture of one of the other of the four packages and asked about the most they would pay for that package."

For the second type of questions, respondents were shown a picture of two carrot packages that differed by one attribute (for example, organic full-sized carrots and conventional full-sized carrots) each of which had price indicates. Respondents chose their preferred selection.

These two formats and questions each make different contributions as explained in Chapters 6 and 7.

My econometric research on the willingness to for carrot product attributes makes three main contributions. First, this research provides several econometric estimates of WTP for the organic attribute and the fresh cut attribute for an important staple vegetable in the U.S. diet. Second, this research compares the contributions of two types of survey questions for empirical investigation of WTP for food product attributes. Third, because I used large-scale web-based surveys, this research is able to explore the variation and robustness of demand parameter estimates across regions, demographic groups, and over time before and during the COVID 19 pandemic. Fourth, this research collected and exploits econometrically a large survey of responses to simple questions. I document the strengths of using an online survey platform with a low cost of collecting responses. I also indicate the limitation of such surveys and the data they provide.

Chapter 5 has six sections. Section 5.1 reviews related literature. Section 5.2 overviews the U.S. carrot industry. Sections 5.3-5.5 explain my survey methods and describe characteristics of respondents and their responses. Section 5.6 summarizes this chapter's findings and suggests implications for the regression model specifications that are used in the subsequent chapters.

5.1. Literature Review

5.1.1. Certified "Organic" Farm Practices as a Food Product Attribute

Certified organic farm practices are frequently claimed through labels on food products. Organic farm practices are more costly than conventional farming per unit of marketable output (Klonsky 2011). Before meeting certification standards, producers assess whether the price premium is enough to compensate for the additional costs for their operation. WTP premiums that some consumers have for claims of organic practices are the market source of compensation for higher cost of production.

The demand for organic foods has been studied for decades across many food categories and regions (See for example: Thompson and Kidwell 1998; Krystallis, Fotopoulos, and Zotos 2006; Bernard and Bernard 2010, which are among the most widely cited of the older studies). Although carrots are a popular vegetable, very little recent research has considered the demand for organic carrots. Lucier and Lin (2007) summarize several demographic factors in U.S. organic carrot consumption patterns but provide few implications for demand parameters. A few studies report evidence on a positive average WTP premium for organic carrots in Canada and several European countries (Scarpa, Thiene, and Marangon 2008; Gschwandtner and Burton 2020). However, the U.S. carrot demand parameters have received little attention in the literature. I estimate the demand parameters for organic carrots in the U.S. retail market.

5.1.2. Fresh Cut as a Food Product Attribute

In this study, fresh-cut practices indicate washing, peeling, and cutting (or any combinations of these practices) vegetables or fruits in preparation for cooking and raw consumption.

Although fresh-cut products have been popular in the United States for decades, only a few economic studies have been conducted on demand for the fresh-cut attributes (Mayen, Marshall, and Lusk 2007; Lacy and Huffman 2016). Those studies deal with a fresh-cut product as an example of food products, but do not estimate the demand for the fresh-cut product attribute. My research estimates the WTP for the fresh-cut attribute and the effect on the shape and position of the willingness to pay function.

My research also relates to the impact of product appearance on food demand. Produce, including crops, fruits, and vegetables, often have what are considered cosmetic defects (e.g., bruises, broken skin, low degree of waxiness, firmness, surface discoloration, non-traditional shape, and non-standard size). Such cosmetic defects often reduce, and possibly eliminate, the market value of produce. A few studies provide evidence about effects on market prices from grocery shopping data (Thompson and Kidwell 1998). Fresh-cut practices can preserve at least part of the value of produces by washing, peeling, and cutting products.

Fresh-cut carrots are useful for analysis for two reasons. First, carrots are widely consumed. Second, fresh-cut carrots are popular in the U.S. retail market. Fresh-cut carrots are often labeled as "baby" carrots in the U.S. retail market when finger-sized small pieces of carrots are sold in a plastic package. In 1986, baby carrots were first introduced by a California farmer who attempted to sell misshapen carrots in retail markets. They grew rapidly in demand after their introduction (Lucier and Lin 2007).

5.1.3. Demand Estimation with Survey Data

I use web-based surveys to obtain data. The survey questionnaires have two distinctive features: (i) Each Survey has only one short question. (ii) Because the data collection was cost effective, I collected about 350,000 responses.

Survey data on willingness to pay raised two methodological issues. First, econometric strategies are needed to reduce the "hypothetical bias" in survey responses. Many economists doubt the usefulness of survey data to elicit demand parameters (Diamond and Hausman 1992; Hausman 2012). Many studies explore how to reduce the impact of the hypothetical bias (Carson 2012; Loomis 2014). Some studies directly ask respondents to answer honestly, often called “cheap talk” in the literature (Cummings and Taylor 1999). Another group of studies asks respondents to swear to tell the truth (Jacquemet, Luchini, and Shogren 2013). Some studies present a separate question to check whether respondents are paying enough attention to survey to provide useful responses (Malone and Lusk 2018).

One common feature of these methods is to make surveys more complicated. To my knowledge, the literature has paid little attention to whether these techniques that make surveys significantly complicated and burdensome for respondents improve the results. The complication is crucial because research in other fields reports that survey complications can affect survey responses (Crawford, Couper, and Lamias 2001; Galesic and Bosnjak 2009).

My research provides an example of a straightforward survey and explores whether this survey design is useful in food demand estimation. This research approach may enhance discussion about (i) the impact of survey complications on food demand estimation and (ii) the trade-off between the survey complication and the reduction of the hypothetical bias when adding special questions to handle the hypothetical bias.

A second group of research studies considers strategies for obtaining useful observations from surveys. Surveys often suggest to respondents a series of WTP questions. For example, in a group of surveys, respondents state whether they would be willing to pay a given price for obtaining a product or a new situation, and they face two or more rounds with different prices (Hanemann, Loomis, and Kanninen 1991; Lusk 2003; Holmquist, McCluskey, and Ross 2012). Another group of surveys suggests two or more products, and respondents select one of them. Usually, in this setup, respondents answer a series of selection questions with different combinations of products (Adamowicz et al. 1998; Alfnes et al. 2006; Ahn and Lusk 2021).

Many questions per respondent can improve the estimation precision but potentially cause a bias. For the first group of studies, some papers are concerned about the potential impact of the first price on the response to the second price (Cameron and Quiggin 1994; Herriges and Shogren 1996; Alberini, Kanninen, and Carson 1997). Similar issues can occur for the second group of studies, although, to my knowledge, similar research has not been conducted for the second group.

My alternative approach is to ask the same simple WTP question of many respondents. Contacting many respondents through traditional methods, including in-person interviews and mail, is costly. However, the cost of contacting many respondents is much cheaper using web-based surveys. My research provides an example of an extensive web-based survey, exploiting low costs of response collection. I use Google Surveys, an online survey platform. It costs only $0.10 per respondent when asking a question per respondent through this online survey platform. This approach and the results presented may raise useful discussions about (i) the trade-off between the precision and the potential bias when asking multiple questions per respondent in food demand estimation and (ii) the benefits and potential costs of web-based surveys in food demand estimation.

5.1.4. COVID-19 and Food Demand

I conducted surveys several times with the same questionnaire and procedures, which generated a set of repeated cross-sectional datasets. This feature allows us to consider the extent to which estimates of demand parameters are robust over time and robust to large exogenous shocks to the market. The robustness of demand parameter estimates is often assumed implicitly when researchers evaluate agricultural and food policies. However, the samples used to generate estimates often have come from different time periods, regions, and demographics compared to the population under the evaluated policies. To my knowledge, little research has been conducted on the robustness of the demand parameters in food consumption.

I use COVID-19 as a significant exogenous shock on food market experiences and conditions. COVID-19 has caused uniquely profound and far-ranging shocks to food markets, including shocks to income, employment, where meals are consumed, and choice of grocery shopping channels (Cranfield 2020; Chang and Meyerhoefer 2021). Clearly, macroeconomic effects (e.g., recessions), and new shopping environments (e.g., online grocery shopping) could affect food demand parameters. However, those factors rarely have been considered in the literature of food demand estimation or use of estimates. This research explores the importance of changes in those factors on the demand parameter estimation using COVID-19.

5.2. The U.S. Carrot Industry: Organic Carrots and Fresh-Cut Carrots

Carrots have been a crucial vegetable and are frequently used in soups, salads, snacks, and desserts. To my knowledge, there is no publicly available information about the per capita consumption of carrots in the United States. The per capita availability was about 16.6 pounds per year in 2019 (USDA-ERS 2020). The per capita availability is calculated by the formula: (domestic production + net import) / the U.S. population. Table 5.1 provides statistics on the domestic production, export, import, and farm price. The per capita availability of carrots is high compared to many other vegetables (USDA-ERS 2020).[1] Despite the popularity of carrots, some

[1] USDA ERS has reported the per capita availability across main agricultural commodities. Based on the 2019 values (pounds per year), among those commodities, only sweet corn (18.9), lettuces (25.1), onions (22.1), tomatoes (88.3), and potatoes (118.8) have a higher per capita availability than carrots (USDA-ERS 2020).

people do not consume carrots because of allergies, tastes, and other reasons, but related public data on the specific share of those consumers are limited.[2]

Organic products are widely available in the U.S. retail carrot market. However, limited data are available about the quantity or the revenue share of organic carrots in the retail market. The U.S. Department of Agriculture (USDA) Agricultural Marketing Service provides retail prices collected from groceries sampled across many U.S. regions. According to USDA-AMS (2020), organic carrots are priced higher than non-organic carrots at retail. The average retail price of organic full-sized carrots was about $1.39 per pound. However, the average retail price of non-organic full-sized carrots was about $0.81 per pound in 2019.

A prominent feature in the U.S. retail carrot market is the popularity of fresh-cut products.[3] Lucier and Lin (2007) project that fresh-cut carrots account for about 64% of the per capita consumption of carrots at home, using the 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals reported by USDA Economic Research Service and the A.C. Nielsen Homescan Panel Data, 1998-2003. To my knowledge, no other recent public data or estimates are available about the retail consumption quantity of fresh-cut carrots. However, retail price data are available. According to USDA-AMS (2020), the average price of non-organic fresh-cut carrots was about $1.23 per pound in 2019, implying an average price premium of $0.42 per pound over non-organic full-sized carrots.

[2] Allergic reactions to carrots have been studied in the food science literature (Ballmer-Weber et al. 2001, 2012).
[3] Some kinds of carrots are small in full-size. Often, those small-sized carrots are also called “baby carrots” in labeling and promotion activities. However, it is known that those small-sized carrots account for a minimal share in the U.S. retail market. Hence, in this chapter, baby carrots indicate products having small pieces of carrots.

Table 5.1. 2019 and 2020 U.S. Fresh Carrot Production, Imports, Exports, and Farm Price

	2019	2020
Domestic production[1]	2,431.1 million pounds	2,229.3 million pounds
Imports[1]	503.8 million pounds	467.1 million pounds
Exports[1]	153.3 million pounds	150.2 million pounds
Average price (current dollars)[2]	$0.25 per pound	$0.26 per pound

[1] I obtain data from USDA-ERS (2020). The numbers for the 2020 year are preliminary.
[2] USDA-ERS (2020) reports yearly average carrot prices in dollars per cwt. The unit cwt is 112 pounds, and we report average prices in dollars per pound.

Table 5.2. 2019 Average Carrot Retail Prices

	Non-organic	Organic
	Unit: $/lb.	
Full-sized	0.81 (0.13)	1.39 (0.18)
Fresh-cut (baby)	1.23 (0.10)	1.80 (0.15)

Source: USDA-AMS (2020).
Note: The source reports weekly carrot prices on average over many retailers. It reports the number of retailers considered each week. The prices in this table are averages over the entire year, weighted by the number of retailers considered. The numbers in parentheses are standard deviations, weighted by the number of retailers in each week. The number of observations for each in four categories is 52, which reflects all the weeks in 2019, except for the organic full-sized category which has 51 weeks. Carrots considered in the calculation include only packaged products.

5.3. An Overview of Survey Design

I distributed questions to online respondents via Google surveys during the following seven periods:

1. December 2019 – January 2020: Total sample size is 64,237.
2. March – April 2020: Total sample size is 48,064.
3. June 2020: Total sample size is 48,039.
4. August 2020: Total sample size is 48,053.
5. October 2020: Total sample size is 48,061.
6. January 2021: Total sample size is 48,059.
7. March 2021: Total sample size is 48,011.

The total number of responses is 352,545 over the seven periods. Survey administration and questionnaires were identical in each period. In all periods, surveys were conducted in English. In the initial set of surveys in December 2019 – January 2020, additional responses were collected about some specific WTP questions that were not repeated in the following rounds.

Each respondent faced one among several alternative short questions. The questions elicited information about carrot demand parameters. One question per respondent means that the number of respondents equals the number of responses to the WTP questions. No background information about the surveys was presented to respondents. No additional questions were presented to collect demographic information about respondents. Each respondent faced a one simple question with four or five alternative responses.

In a question about willingness to pay for carrots, the first option was always “I don’t buy carrots” for all respondents regardless of the specific question. I included this option because the population of interest is the U.S. carrot buyers rather than the U.S. population as a whole.

Therefore, the survey did not gather information about preference of consuming carrots, considering that some people buy carrots not only for their consumption but for other household members. Also, some respondents do not pay sufficient attention to the survey, and this option gives those respondents an opportunity to leave the survey immediately.

The share of respondents selecting this first option was about 15% of the total, and this percentage varied little across specific survey questions or different further alternatives or across the time periods. Overall, respondents selecting "I don't buy carrots" were similar to other respondents in demographics (Section 5.4).

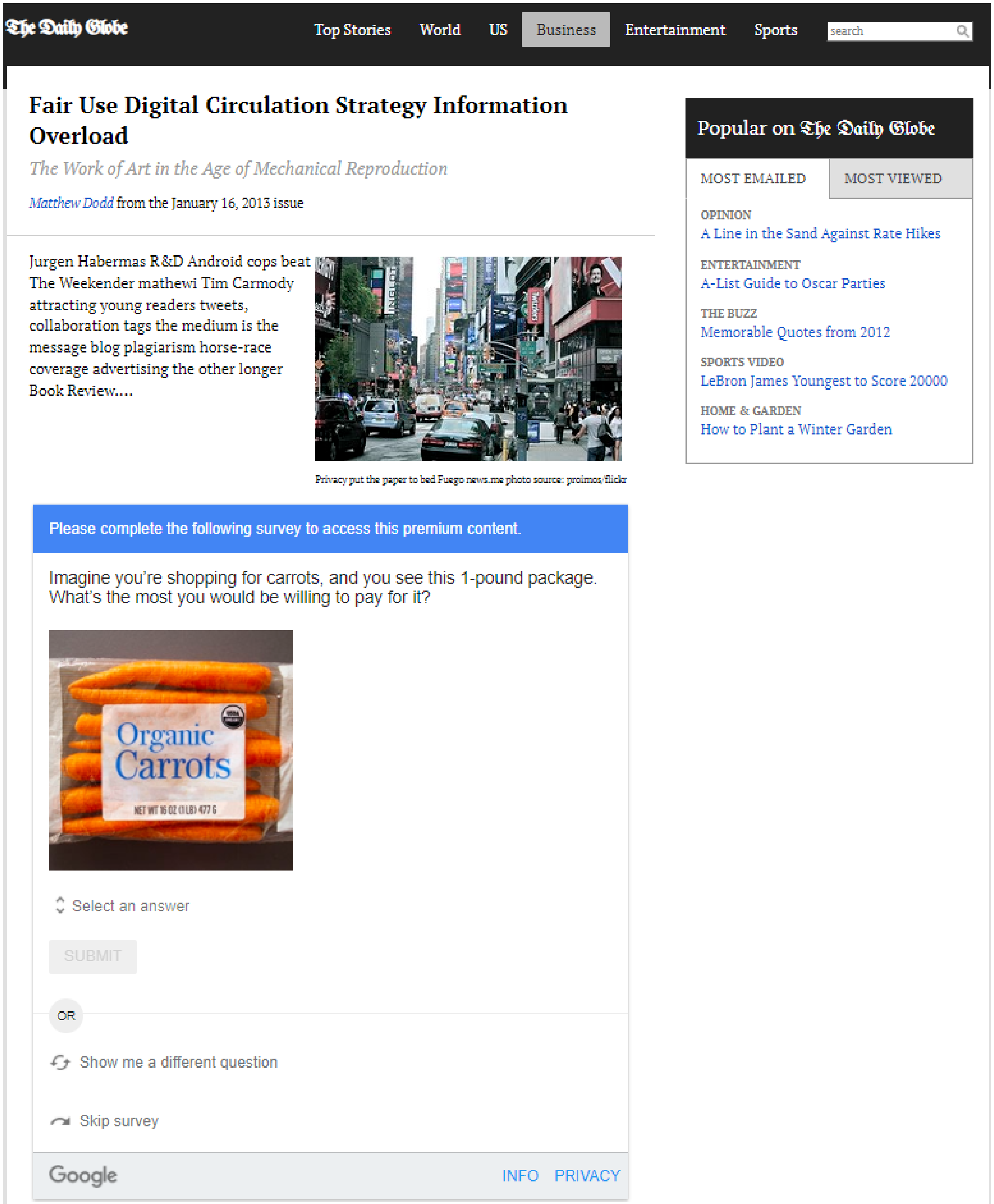
I used Google Surveys, an online platform that distributes surveys through about 1,500 mainstream websites featuring news, arts, and entertainment. Examples of participating websites include Gannett regional newspapers, USA Today, the Financial Times, and Woman's World. The Google process partially blocks the contents of a website, and visitors to that website must answer a very short set of questions to access the blocked contents. Google Surveys selects respondents randomly within demographic groups, including geography. Figure 5.1 shows an example of surveys distributed through Google Surveys.

Google Surveys has been used in economics, marketing, and other fields to elicit consumer preferences and political attitudes (Frederick, Lee, Baskin 2014; Stephens-Davidowitz, and Varian 2015; Brynjolfsson, Collis, and Eggers 2019). Although many studies have used online surveys to explore food demand (Gao and Schroeder 2009; Waterfield, Kaplan, and Zilberman 2020), I know no other food demand papers that have collected a large sample of responses using simple online surveys such as Google Surveys to elicit preferences or demand parameters.

Google Surveys has several features that suggest its usefulness as a promising survey platform in food demand estimation. First, it is cheap per response relative to other survey platforms. Over our survey period, the cost was $0.10 per respondent for a single-question survey.[4] Second, it is quick to collect responses compared to other survey platforms. This research took about one week to collect the responses in each period. Third, despite the low price and the quick collection, it provides random samples providing demographic information similar to the U.S. population. Fourth, using an anonymous survey with no preamble avoids bias from respondent reactions to survey personnel or other signals about what might be favored responses Finally, given the large sample sizes that are feasible, it provides demographic information from respondents without asking demographic questions that may be sensitive to those surveyed.

[4] The price per a question is higher when responses are collected from targeted groups of demographics (gender, age, and region). Also, the price per a question is higher when a screening question is added. The number of questions also raise the price per a question. See Google Surveys' pricing: https://support.google.com/surveys/answer/2447244?hl=en.

Figure 5.1. An Example of Surveys Distributed through Google Surveys



5.4. Descriptive Statistics on Demographics

Google Surveys provides inferred respondent characteristics (age, gender, and region) based on internet use rather than reported demographics by respondents to represent the general population of internet users. Google collects demographic information of their users when they make an account or while they use Google's service. Google identifies general demographic information about websites when sufficient Google users visit those websites. Given this demographic information specific to websites, Google infers visitors' demographic information.

Google Surveys cannot collect data from non-internet users, but the share of internet users in the U.S. population was about 91% in 2020 (World Bank 2022). Google Surveys cannot obtain responses from non-internet users, but it is not rare that responses from part of the population are not collected in survey studies. For example, survey studies often collected responses from only college students (e.g., Lusk et al. 2001), people in a local region (Meas et al. 2014), and customers in a store (e.g., Gustafson, Lybbert, and Sumner 2016). Several papers have found evidence that the inferred demographics of Google Surveys provided representative samples of the U.S. population and reliable estimation results (McDonald, Mohebbi, and Slatkin 2013; Hulland and Miller 2018).

Table 5.3 reports respondent shares by demographics. The numbers in parentheses are the corresponding 95% confidence intervals. Table 5.3 reports the results by three different samples: (i) a subsample including only respondents who selected "I don't buy carrots," (ii) a subsample including only respondents who did not select that option, and (iii) the full sample.

Table 5.3 shows important patterns in the data about inferring demographics. Google inferred gender, age category and region based on search patterns and other information about the URL of the respondent computer. The shares of respondents without inferred demographic information was about 20% for gender and age, but negligible for region. The gender was not inferred for about 18% of respondents in the full sample. The age group was not inferred for about 20% of respondents. The geographical location was inferred for more than 99% of respondents. The shares of "not inferred" are slightly higher in the respondents selecting "I don't buy carrots" than the other respondents.

Table 5.4 excludes respondents for whom Google Surveys did not infer the full set of demographics, presumably because they did not have sufficient information on that respondent. The overall sample shares are similar to the U.S. population shares. The share selecting "I don't buy carrots" is more male and younger than those who responded to the carrots purchase choices and the U.S. population. The gender pattern in the total sample is very similar to the U.S. population. The age range is slightly more middle aged with fewer 25-34 and fewer over 65. In addition, a smaller share of respondents is in the Northeast and South and more are in Midwest relative to the U.S. population.

Given the findings of this section, I consider the following points in the model specification of Chapters 6 and 7. First, I include demographic variables as explanatory variables. Second, I use sampling weights based on demographic groups to make the sample represent the population.

Table 5.3. Demographics for Subsamples Differentiated Selection of the Option, "I Don't Buy Carrots."

Demographics	Respondents selecting "I don't buy carrots."	Excluding respondents selecting "I don't buy carrots."	Full sample
Gender			
Male	45.7 (45.2, 46.1)	39.0 (38.8, 39.2)	40.0 (39.8, 40.1)
Female	35.3 (34.9, 35.7)	43.1 (42.9, 43.3)	41.9 (41.8, 42.1)
Not inferred	19.1 (18.7, 19.4)	17.9 (17.8, 18.0)	18.1 (17.9, 18.2)
Age			
18 – 24	10.2 (9.9, 10.4)	6.8 (6.7, 6.9)	7.3 (7.2, 7.4)
25 – 34	17.0 (16.6, 17.3)	13.4 (13.3, 13.5)	13.9 (13.8, 14.0)
35 – 44	14.8 (14.5, 15.1)	14.2 (14.1, 14.3)	14.3 (14.2, 14.4)
45 – 54	13.7 (13.4, 14.0)	14.8 (14.7, 15.0)	14.7 (14.5, 14.8)
55 – 64	12.6 (12.3, 12.9)	16.3 (16.1, 16.4)	15.7 (15.6, 15.8)
65 +	10.2 (10.0, 10.5)	14.7 (14.6, 14.9)	14.1 (14.0, 14.2)
Not inferred	21.6 (21.3, 22.0)	19.7 (19.6, 19.9)	20.0 (19.9, 20.1)
Region			
Northeast	13.6 (13.3, 13.9)	13.5 (13.3, 13.6)	13.5 (13.4, 13.6)
Midwest	28.3 (27.9, 28.7)	30.2 (30.1, 30.4)	30.0 (29.8, 30.1)
South	38.2 (37.8, 38.6)	33.6 (33.4, 33.8)	34.3 (34.1, 34.4)
West	19.7 (19.4, 20.0)	22.6 (22.4, 22.7)	22.1 (22.0, 22.3)
Not inferred	0.18 (0.15, 0.22)	0.14 (0.13, 0.16)	0.15 (0.14, 0.16)
Number of observations	51,221	301,324	352,545

Notes. The unit is a percentage. The numbers in parentheses are the corresponding 95 percent confidence intervals. The term, "not inferred," in each demographics category indicates the group of respondents whose demographics are not inferred. All the respondents are aged 18 or more.

Table 5.4. Demographics for Subsamples Differentiated Selection of the Option, "I Don't Buy Carrots," Excluding Respondents Whose Demographics are Not Inferred

Demographics	Respondents with all demographic information (Aged 18 or more only)[1]			The U.S. Population[2]
	Respondents selecting "I don't buy carrots."	Excluding respondents selecting "I don't buy carrots."	Total	
Gender				
Male	56.8 (56.3, 57.2)	47.1 (46.8, 47.3)	48.9 (48.7, 49.1)	49.2
Female	43.2 (42.7, 43.7)	53.0 (52.7, 53.2)	51.1 (50.9, 51.3)	50.8
Age				
18 – 24	12.5 (12.1, 12.8)	8.3 (8.2, 8.4)	9.1 (9.0, 9.2)	8.7[3]
25 – 34	20.7 (20.2, 21.1)	16.4 (16.3, 16.6)	17.4 (17.3, 17.5)	18.5
35 – 44	18.7 (18.3, 19.1)	17.8 (17.6, 18.0)	17.9 (17.7, 18.0)	17.0
45 – 54	18.0 (17.6, 18.4)	18.8 (18.6, 19.0)	18.3 (18.2, 18.5)	16.6
55 – 64	16.7 (16.3, 17.1)	20.5 (20.3, 20.7)	19.7 (19.5, 19.8)	17.2
65 +	13.5 (13.1, 13.8)	18.2 (18.0, 18.4)	17.6 (17.5, 17.8)	21.9
Region				
Northeast	13.3 (12.9, 13.7)	12.9 (12.8, 13.1)	13.1 (13.0, 13.2)	17.4[4]
Midwest	29.2 (28.7, 29.7)	31.3 (31.1, 31.5)	30.7 (30.6, 30.9)	20.8
South	38.4 (37.9, 38.9)	33.6 (33.3, 33.8)	34.4 (34.2, 34.6)	38.1
West	19.1 (18.6, 19.5)	22.3 (22.1, 22.4)	21.8 (21.6, 21.9)	23.7
Number of observations	40,084	241,537	281,621	-

Notes. The unit is a percentage. The numbers in parentheses are the corresponding 95 percent confidence intervals. As shown in Table 5.3, some respondents were not inferred in demographics, and these respondents are excluded in this table. The shares are calibrated again to make the sum 100% after the exclusion.
[1] The number of observations of the whole sample includes those under 18 and those without demographics.

[2] The data about regional groups come from 2020 Decennial Census Public Law 94-171 Redistricting Data. However, this source does not provide gender and age profiles. Instead, I obtained gender and age group shares from the American Community Survey in 2019. The source reports estimates of the numbers of people by age group. I consider people aged 18 or more only and calculate the share of each group.
[3] I obtained the data about the American Community Survey from data.census.gov, which provides descriptive tables. There is no 18-24 age group in the source, so I used the 20-24 age group instead.
[4] Decennial Census Public Law 94-171 Redistricting Data in 2020 provides state population. I matched states with four regions and calculated the shares. Because the source does not provide population by state, the population numbers used in the calculation include people aged less than 18.

5.5. Descriptive Statistics on Response Time

Google Surveys also provide information about how long individual respondents elapsed between when the survey was opened and when it was completed. I explore the response time because several prior studies using online responses found that the inclusion of response times as a control in statistical estimation reduced random responses and standard errors of estimated parameters (Haaijer et al. 2000; Rose and Black 2006). The concern is that respondents that are too quick may not be actually reading the questions, and respondents that take too long were likely interrupted in their responses.

Table 5.5 reports descriptive statistics on the response time by the WTP question types, the choice of "I don't buy carrots," and whether inferred demographics were provided. The table includes ten categories. Three features are common across the categories. First, the average response time is slightly less than 30 seconds for most categories. Second, the standard deviation within each category is high relative to the average for all the categories in the table. Third, the min and max values are substantially different from the average in each category.

Three points are noticeable in comparison with categories. First, on average, respondents took about the same time for the Yes-No questions (about 28 seconds on average) as the Multiple-Choice questions (about 27 seconds on average). Second, respondents choosing "I don't buy carrots" tended to spend less than the other respondents. Third, on average, respondents without inferred demographics spent more than those with demographics.

Based on the findings of this section, I consider the following model specification in Chapters 6 and 7. First, I include the response time as an explanatory variable in regressions. Second, I compare the models with and without outliers in response time. The outliers include both those with a very short response time and a very long response time because the relationship between response time and response reliability is possibly not linear (Börger 2016). A very long response time possibly indicates insufficient attention to the survey because respondents often do multiple activities simultaneously on the internet.

Table 5.5. Descriptive Statistics on Response Time by the WTP Questions, the Choice of "I Don't Buy Carrots," and Whether Demographics are Inferred

		Number of observations	Share	Mean	Standard deviation	Min	Max
Units		Numbers	%	Seconds	Seconds	Seconds	Seconds
Panel A. Multiple-choice questions							
Choose "I don't buy carrots"	Yes	8,955	14.9%	25.9	94.3	1.0	2724.5
	No	51,141	85.1%	27.0	87.5	0.6	3586.0
Demographics	Not inferred	12,171	20.3%	28.1	77.5	1.1	2651.8
	Inferred	47,925	79.7%	26.6	91.2	0.6	3586.0
Subsample, total		60,096		26.9	88.6	0.6	3586.0
Panel B. Yes-No questions							
Choose "I don't buy carrots"	Yes	42,266	14.5%	25.0	91.0	0.7	3400.2
	No	250,183	85.5%	28.7	91.9	0.6	3554.9
Demographics	Not inferred	58,753	20.1%	30.9	101.3	0.9	3554.9
	Inferred	233,696	79.9%	27.5	89.2	0.6	3540.8
Subsample, total		292,449		28.2	91.8	0.6	3554.9
Full sample, total		352,545		27.9	91.2	0.6	3586.0

5.6. Summary of Findings and Implications for Model Specification

Chapter 5 overviews prior research, presents some industry and market facts, and explores the data used in subsequent chapters.

I conducted online surveys to obtain data on willingness to pay for carrots and specifically carrot attributes. Through Sections 5.4 and 5.5, I explore the survey responses. Primary findings are: (i) Overall, the inferred demographics of the full sample are similar to the U.S. population (Section 5.4). (ii) Response time differs across respondents with a few extreme outliers (Section 5.5).

Given this background, I turn, in Chapters 6 and 7, to the estimation of a series of alternative samples and model specifications for willingness to pay for carrots. First, I specify and report regression results using sampling weights based on demographic groups to adjust the difference in demographics between the sample and the population. Second, I include response time as an explanatory variable to analyze whether it affects the regression results. Third, I exclude respondents choosing the option, “I don’t buy carrots,” in estimating the parameters of the WTPs for carrot attributes to focus on the U.S. carrot buyers rather than the U.S. population. Fourth, I report the results of models, including period dummies, to analyze whether the results are sensitive to periods.

Appendix 5.A. Demographics by the WTP Question Types

I use two types of WTP question approaches. Section 5.4 reports descriptive statistics on demographics, and this appendix examines whether demographic information differs between groups of respondents suggested by different WTP question types.

Tables 5.A.1 shows that there are no differences in demographic statistics or whether demographic information was inferred by which WTP question type was asked. As explained in Section 5.3, Google Surveys reports demographic information inferred based on the internet usage of respondents, and it fails to infer demographic information when there is no sufficient information about internet usage. Table 5.A.2 includes only respondents with demographics inferred for gender, age group, and region. After excluding respondents without demographic information, the results of the samples are similar to the U.S. population, with a few exceptions: Slightly more 18 -24 aged people responded to the surveys compared to the population. The response shares of people in the Northeast and South are high, while the share of Midwest is low, compared to the population.

Table 5.A.1. Demographics by the WTP Question Types

Demographics	Respondents to Multiple-Choice questions	Respondents to Yes-No questions	Full sample
Gender			
Male	40.5 (40.2, 40.9)	39.9 (39.7, 40.0)	40.0 (39.8, 40.1)
Female	41.1 (40.7, 41.5)	42.1 (41.9, 42.3)	41.9 (41.8, 42.1)
Not inferred	18.4 (18.0, 18.7)	18.0 (17.9, 18.2)	18.1 (17.9, 18.2)
Age			
18 – 24	7.3 (7.1, 7.5)	7.3 (7.2, 7.4)	7.3 (7.2, 7.4)
25 – 34	14.1 (13.8, 14.4)	13.9 (13.8, 14.0)	13.9 (13.8, 14.0)
35 – 44	14.2 (13.9, 14.5)	14.3 (14.2, 14.4)	14.3 (14.2, 14.4)
45 – 54	14.9 (13.9, 14.5)	14.6 (14.5, 14.7)	14.7 (14.5, 14.8)
55 – 64	15.6 (15.3, 15.9)	15.8 (15.6, 15.9)	15.7 (15.6, 15.8)
65 +	13.8 (13.5, 14.1)	14.1 (14.0, 14.3)	14.1 (14.0, 14.2)
Not inferred	20.1 (19.8, 20.5)	20.0 (19.8, 20.1)	20.0 (19.9, 20.1)
Region			
Northeast	13.5 (13.2, 13.7)	13.4 (13.4, 13.6)	13.5 (13.4, 13.6)
Midwest	29.8 (29.4, 30.2)	30.0 (34.1, 34.4)	30.0 (29.8, 30.1)
South	34.4 (34.1, 34.8)	34.2 (34.1, 34.4)	34.3 (34.1, 34.4)
West	22.1 (21.8, 22.5)	22.1 (22.0, 22.3)	22.1 (22.0, 22.3)
Not inferred	0.15 (0.12, 0.18)	0.15 (0.13, 0.16)	0.15 (0.14, 0.16)
Number of observations	60,096	292,449	352,545

Notes. The unit is a percentage. The numbers in parentheses are the corresponding 95 percent confidence intervals. The term, “not inferred,” in each demographics category indicates the group of respondents whose demographics are not inferred. All the respondents are aged 18 or more.

Table 5.A.2. Demographics by the WTP Question Types after Excluding Respondents Whose Demographics are Not Inferred

Demographics	Respondents with all demographic information (Aged 18 or more only)[1]			The U.S. Population[2]
	Respondents to Multiple Choice Questions	Respondents to Yes/No Questions	Total	
Gender				
Male	49.8 (49.3, 50.2)	48.8 (48.6, 49.0)	48.9 (48.7, 49.1)	49.2
Female	50.2 (49.8, 50.7)	51.2 (51.0, 51.4)	51.1 (50.9, 51.3)	50.8
Age				
18 – 24	9.1 (8.9, 9.3)	9.1 (9.0, 9.2)	9.1 (9.0, 9.2)	8.7[3]
25 – 34	17.7 (17.3, 18.0)	17.4 (17.2, 17.5)	17.4 (17.3, 17.5)	18.5
35 – 44	17.8 (17.4, 18.1)	17.9 (17.7, 18.0)	17.9 (17.7, 18.0)	17.0
45 – 54	18.6 (18.3, 19.0)	18.3 (18.1, 18.4)	18.3 (18.2, 18.5)	16.6
55 – 64	19.5 (19.2, 19.9)	19.7 (19.5, 19.9)	19.7 (19.5, 19.8)	17.2
65 +	17.3 (17.0, 17.6)	17.7 (17.5, 17.8)	17.6 (17.5, 17.8)	21.9
Region				
Northeast	13.0 (12.7, 13.3)	13.1 (13.0, 13.3)	13.1 (13.0, 13.2)	17.4[4]
Midwest	30.7 (30.3, 31.1)	30.7 (30.5, 30.9)	30.7 (30.6, 30.9)	20.8
South	34.6 (34.1, 35.0)	34.3 (34.1, 34.5)	34.4 (34.2, 34.6)	38.1
West	21.7 (21.4, 22.1)	21.8 (21.6, 22.0)	21.8 (21.6, 21.9)	23.7
Number of observations	47,925	233,696	281,621	-

Notes. The unit is a percentage. The numbers in parentheses are the corresponding 95 percent confidence intervals. As shown in Table 5.3, some respondents were not inferred in demographics, and these respondents are excluded in this table. The shares are calibrated again to make the sum 100% after the exclusion.
[1] The number of observations of the whole sample includes those under 18 and those without demographics.
[2] The data about regional groups come from 2020 Decennial Census Public Law 94-171 Redistricting Data. However, this source does not provide gender and age profiles. Instead, I

obtained gender and age group shares from the American Community Survey in 2019. The source reports estimates of the numbers of people by age group. I consider people aged 18 or more only and calculate the share of each group.
[3] I obtained the data about the American Community Survey from data.census.gov, which provides descriptive tables. There is no 18-24 age group in the source, so I used the 20-24 age group instead.
[4] Decennial Census Public Law 94-171 Redistricting Data in 2020 provides state population. I matched states with four regions and calculated the shares. Because the source does not provide population by state, the population numbers used in the calculation include people aged less than 18.

Appendix 5.B. Determinants of Response Time

This appendix examines determinants of the response time of respondents. For this purpose, I regress the response time on (i) whether to choose "I don't buy carrots" (one if chosen, otherwise zero) (ii) whether to face a Multiple-Choice question (one if facing a Multiple-Choice question, and zero if facing a Yes-No question), (iii) female (one if female, and zero if male), (iv) age group dummies (the base is the 18 – 24 aged group), and (v) region group dummies (the base is Northeast). I use the standard linear regression with the robust standard errors (White-Huber standard errors) to handle the heteroskedasticity.

Table 5.B.1 reports the results of four regressions characterized by different samples and explanatory variables. Models 1 and 2 use the full sample. Models 3 and 4 include only respondents with demographics. Models 1 and 3 include the choice of "I don't buy carrots" as an explanatory variable, but Models 2 and 4 do not, which is to consider that the choice of "I don't buy carrots" is possibly endogenous.

Five points are noticeable in the regression results. First, the results of Model 1 confirm the findings from Table 5.5 about (i) the choice of "I don't buy carrots," (ii) whether respondents faced a Multiple-Choice question, (iii) whether demographics are inferred. Second, female respondents spent less time than male respondents. Third, compared to the 18 – 24 aged respondents, those aged between 25 – 54 spent less time, while those aged more than 54 spent more time. Fourth, compared to the Northeast respondents, those in other regions (Midwest, South, and West) spent less time. Fifth, the coefficient estimates are robust with and without the choice of "I don't buy carrots" as an explanatory variable.

Table 5.B.1. Determinants of Response Time: Linear Regression Results

		Full sample		Only with demographics	
		Model 1	Model 2	Model 3	Model 4
Choose "I don't buy carrots"		-3.30 (0.437)	-	-3.55 (0.485)	-
Face a Multiple-Choice question		-1.28 (0.399)	-1.30 (0.399)	-0.928 (0.455)	-0.932 (0.455)
Demographics are inferred		-3.11 (0.404)	-3.06 (0.404)	-	-
Female		-	-	-2.42 (0.340)	-2.27 (0.339)
Age	18 – 24	-	-	Base	Base
	25 – 34	-	-	-1.64 (0.847)	-1.55 (0.847)
	35 – 44	-	-	-4.37 (0.798)	-4.18 (0.797)
	45 – 54	-	-	-2.72 (0.800)	-2.48 (0.799)
	55 – 64	-	-	0.0380 (0.782)	0.342 (0.779)
	65+	-	-	3.23 (0.782)	3.58 (0.776)
Region	Northeast	-	-	Base	Base
	Midwest	-	-	-4.45 (0.602)	-4.41 (0.602)
	South	-	-	-1.72 (0.606)	-1.78 (0.605)
	West	-	-	-2.02 (0.648)	-1.96 (0.649)
Constant		31.1 (0.384)	30.6 (0.379)	32.6 (0.878)	31.8 (0.869)
R-squared		0.0004	0.0002	0.0015	0.0013
F-statistic		41.1	32.2	53.0	47.8
P-value		0.000	0.000	0.000	0.000
Number of observations		352,545	352,545	281,621	281,621

Notes. Models 1 and 2 use the full sample. Models 3 and 4 include only respondents with demographics. Models 1 and 3 include the choice of "I don't buy carrots" as an explanatory variable, but Models 2 and 4 do not. The dependent variable is the response time (the unit is a second). The numbers in parentheses are the robust standard error (White-Huber standard error).

Appendix 5.C. Descriptive Statistics on Demographics and Response Time by Periods

I conducted surveys seven times using the same questionnaires and administrative procedures. This appendix explores whether demographic information is substantially different by different survey periods.

Table 5.C.1 reports descriptive statistics on demographics, the choice of "I don't buy carrots," and the response time by seven periods. The numbers in demographics and the choice of "I don't buy carrots" are response shares. The response time row reports the mean values (in seconds). The numbers in parentheses are 95% confidence intervals.

The shares of male, female, and respondents whose gender is not inferred differ across periods. The male shares are higher than the female shares in three periods (December 2019 – January 2020, January 2021, and March 2021) but lower in the other periods. The shares of "not inferred" are about 20% over three periods (December 2019 – January 2020, March – April 2020, and June 2020), but they fell to about 10% in the following two periods (August 2020 and October 2020), and then they rose back to about 20% in the following two periods (January 2021 and March 2021).

The shares of age groups also differ across periods. For example, the shares of the 18 – 24 age group range from 4.8% to 8.9%. There is no monotonic pattern of the changes over periods. The shares of "not inferred" group change similarly to the case of gender.

The shares of regional groups were less variable over the rounds of the survey than gender and age groups, in part because region was inferred for more than 99% of respondents in all periods. However, there are slight variations in Northeast, Midwest, and South shares. For example, the share of Northeast was about 15% in December 2019 – January 2020, then fell to about 12% to 13.5%, except for January 2021 when it was almost 15% like it had been one year earlier.

The shares of respondents choosing the option, "I don't buy carrots," are less variable over time period than gender and age groups described above. There is no monotonic trend over periods. The shares are about 14% in several periods during the pandemic periods (March 2020, August 2020, October 2020, and January 2021), which is about 1% lower than that in December 2019 – January 2020. However, the shares are near 15% in the other two periods during the pandemic (June 2020 and March 2021).

The average response time was approximately 34 seconds in the December 2019 – January 2020 survey. The average response times range from about 23 seconds to 28 seconds from June 2020 to March 2021.

Table 5.C.2 compares survey respondent demographics over survey rounds with the U.S. population data cited earlier. This table includes only respondents whose demographics are inferred. The demographic group differences between each period subsample and the population vary over periods. However, overall, there is no dramatic change. One pattern of interest is that the share of the 18 – 24 aged group has declined over survey rounds except for a slight rise for the June 2020 survey.

Table 5.C.1. Descriptive Statistics on Demographics, Choice of "I Don't Buy Carrots," and Response Time over Periods over Periods

Demographics		December 2019 – January 2020	March – April 2020	June 2020	August 2020
Gender	Male	39.9 (39.5, 40.9)	34.8 (34.3, 35.2)	39.5 (39.1, 39.9)	41.0 (40.5, 41.4)
	Female	39.8 (39.4, 40.1)	46.0 (45.5, 46.4)	40.6 (40.1, 41.0)	48.4 (47.9, 48.8)
	Not inferred	20.4 (20.1, 20.7)	19.3 (18.9, 19.6)	19.9 (19.6, 20.3)	10.6 (10.4, 10.9)
Age	18 – 24	8.8 (8.6, 9.0)	7.1 (6.9, 7.3)	8.9 (8.7, 9.2)	8.1 (7.9, 8.4)
	25 – 34	13.6 (13.4, 13.9)	14.3 (14.0, 14.6)	14.5 (14.1, 14.8)	15.5 (15.2, 15.8)
	35 – 44	13.7 (13.4, 14.0)	14.3 (14.0, 14.6)	14.6 (14.3, 14.9)	16.2 (15.9, 16.5)
	45 – 54	14.1 (13.8, 14.3)	13.9 (13.6, 14.2)	13.3 (13.0, 13.6)	17.3 (17.0, 17.7)
	55 – 64	14.0 (13.8, 14.3)	14.9 (14.6, 15.3)	13.7 (13.4, 14.0)	16.5 (16.2, 16.8)
	65 +	12.9 (12.6, 13.1)	14.1 (13.8, 14.4)	11.9 (11.6, 12.2)	14.3 (13.9, 14.6)
	Not inferred	22.9 (22.6, 23.3)	21.4 (21.1, 21.8)	23.2 (22.8, 23.6)	12.0 (11.7, 12.3)
Region	Northeast	15.5 (15.2, 15.8)	12.1 (11.9, 12.4)	12.4 (12.1, 12.7)	12.4 (12.1, 12.7)
	Midwest	27.3 (27.0, 27.7)	32.1 (31.7, 32.5)	28.3 (27.9, 28.7)	29.9 (29.5, 30.3)
	South	34.0 (33.7, 34.3)	33.0 (32.6, 33.4)	36.4 (36.0, 36.8)	35.3 (34.9, 35.8)
	West	22.9 (22.6, 23.2)	22.6 (22.3, 23.0)	22.8 (22.4, 23.2)	22.2 (21.8, 22.6)
	Not inferred	0.25 (0.21, 0.29)	0.096 (0.072, 0.13)	0.098 (0.074, 0.13)	0.13 (0.10, 0.17)
Choose "I don't buy carrots"		15.4 (15.1, 15.7)	14.0 (13.7, 14.3)	14.9 (14.6, 15.3)	14.3 (14.0, 14.6)
Response time (mean, seconds)		33.5 (32.6, 34.4)	32.4 (31.4, 33.4)	27.7 (27.0, 28.5)	27.7 (26.9, 28.6)
Number of observations		64,237	48,064	48,039	48,053

Table 5.C.1. Descriptive Statistics on Demographics, Choice of "I Don't Buy Carrots," and Response Time over Periods over Periods (continued)

Demographics		October 2020	January 2021	March 2021	Full sample
Gender	Male	43.7 (43.2, 44.1)	41.6 (41.2, 42.1)	39.5 (39.1, 39.9)	40.0 (39.8, 40.1)
	Female	47.4 (47.0, 47.9)	37.9 (37.4, 38.3)	34.4 (34.0, 34.8)	41.9 (41.8, 42.1)
	Not inferred	8.9 (8.6, 9.2)	20.5 (20.1, 20.9)	26.1 (25.7, 26.5)	18.1 (17.9, 18.2)
Age	18 – 24	7.6 (7.4, 7.8)	5.4 (5.2, 5.6)	4.8 (4.6, 5.0)	7.3 (7.2, 7.4)
	25 – 34	16.5 (16.2, 16.9)	12.3 (12.0, 12.6)	10.9 (10.6, 11.2)	13.9 (13.8, 14.0)
	35 – 44	16.5 (16.2, 16.8)	12.9 (12.6, 13.2)	12.0 (11.7, 12.3)	14.3 (14.2, 14.4)
	45 – 54	17.1 (16.7, 17.4)	14.4 (14.1, 14.7)	12.7 (12.4, 13.0)	14.7 (14.5, 14.8)
	55 – 64	17.5 (17.1, 17.8)	17.4 (17.0, 17.7)	16.7 (16.4, 17.0)	15.7 (15.6, 15.8)
	65 +	15.0 (14.7, 15.3)	15.2 (14.9, 15.5)	15.7 (15.4, 16.1)	14.1 (14.0, 14.2)
	Not inferred	9.8 (9.6, 10.1)	22.4 (22.1, 22.8)	27.1 (26.7, 27.5)	20.0 (19.9, 20.1)
Region	Northeast	13.2 (12.9, 13.5)	14.7 (14.4, 15.0)	13.2 (12.9, 13.5)	13.5 (13.4, 13.6)
	Midwest	33.5 (33.1, 33.9)	28.2 (27.8, 28.6)	31.3 (30.9, 31.8)	30.0 (29.8, 30.1)
	South	32.1 (31.7, 32.5)	34.8 (34.4, 35.2)	34.2 (33.8, 34.7)	34.3 (34.1, 34.4)
	West	21.1 (20.7, 21.5)	22.1 (21.8, 22.5)	21.0 (20.6, 21.4)	22.1 (22.0, 22.3)
	Not inferred	0.10 (0.077, 0.13)	0.12 (0.093, 0.16)	0.20 (0.16, 0.24)	0.15 (0.14, 0.16)
Choose "I don't buy carrots"		14.0 (13.7, 14.3)	14.0 (13.7, 14.3)	14.8 (14.5, 15.1)	14.5 (14.4, 14.6)
Response time (mean, seconds)		22.7 (22.1, 23.3)	24.4 (23.8, 25.0)	25.3 (24.6, 26.0)	27.9 (27.6, 28.2)
Number of observations		48,061	48,059	48,032	352,545
Notes. The unit of the values by demographics and choosing "I don't buy carrots" is a percentage. The response time reports the mean values whose unit is a second. The numbers in parentheses are 95 percent confidence intervals. The term, "not inferred," in each					

demographics category indicates the group of respondents whose demographics are not inferred.

Table 5.C.2. Descriptive Statistics on Demographics, Choice of "I Don't Buy Carrots," and Response Time over Periods over Periods, Only Respondents Whose Demographics are Inferred

Demographics		December 2019 – January 2020	March – April 2020	June 2020	August 2020
Gender	Male	50.4 (49.9, 50.8)	43.2 (42.7, 43.7)	49.6 (49.1, 50.1)	45.9 (45.4, 46.4)
	Female	49.6 (49.2, 50.1)	56.8 (56.3, 57.3)	50.4 (49.9, 50.9)	54.1 (53.6, 54.6)
Age	18 – 24	11.4 (11.1, 11.7)	9.0 (8.8, 9.3)	11.6 (11.3, 11.9)	9.2 (8.9, 9.5)
	25 – 34	17.7 (17.3, 18.0)	18.2 (17.8, 18.5)	18.8 (18.4, 19.2)	17.6 (17.3, 18.0)
	35 – 44	17.8 (17.4, 18.1)	18.2 (17.8, 18.6)	19.0 (18.6, 19.4)	18.4 (18.1, 18.8)
	45 – 54	18.2 (17.9, 18.6)	17.7 (17.3, 18.1)	17.3 (16.9, 17.7)	19.7 (19.4, 20.1)
	55 – 64	18.2 (17.9, 18.6)	19.0 (18.6, 19.4)	17.8 (17.4, 18.2)	18.8 (18.4, 19.1)
	65 +	16.7 (16.4, 17.0)	17.9 (17.5, 18.3)	15.5 (15.1, 15.9)	16.2 (15.9, 16.6)
Region	Northeast	15.3 (15.0, 15.7)	11.7 (11.4, 12.0)	12.1 (11.7, 12.4)	12.1 (11.8, 12.5)
	Midwest	27.5 (27.1, 27.9)	32.1 (31.6, 32.5)	28.1 (27.7, 37.4)	31.1 (30.7, 31.5)
	South	34.5 (34.1, 34.9)	33.6 (33.1, 34.0)	36.9 (36.4, 37.4)	35.0 (34.6, 35.5)
	West	22.7 (22.3, 23.0)	22.7 (22.2, 23.1)	22.9 (22.5, 23.4)	21.7 (21.3, 22.1)
Choose "I don't buy carrots"		14.9 (14.6, 15.2)	13.7 (13.4, 14.1)	14.6 (14.3, 15.0)	14.0 (13.7, 14.4)
Response time (mean, seconds)		32.6 (31.6, 33.7)	31.6 (30.4, 32.7)	26.7 (25.9, 27.5)	26.7 (25.9, 27.5)
Number of observations		49,366	37,729	36,869	42,217

Table 5.C.2. Descriptive Statistics on Demographics, Choice of “I Don’t Buy Carrots,” and Response Time over Periods over Periods, Only Respondents Whose Demographics are Inferred (continued)

Demographics		October 2020	January 2021	March 2021	The U.S. population[1]
Gender	Male	48.0 (47.5, 48.5)	52.4 (51.9, 52.9)	53.6 (53.0, 54.1)	49.2
	Female	52.0 (51.5, 52.5)	47.6 (47.1, 48.1)	46.4 (45.9, 47.0)	50.8
Age	18 – 24	8.4 (8.2, 8.7)	6.9 (6.7, 7.2)	6.5 (6.2, 6.8)	8.7[2]
	25 – 34	18.3 (18.0, 18.7)	15.8 (15.5, 16.2)	15.0 (14.6, 15.3)	18.5
	35 – 44	18.3 (17.9, 18.7)	16.7 (16.3, 17.0)	16.5 (16.1, 16.9)	17.0
	45 – 54	18.9 (18.6, 19.3)	18.6 (18.2, 19.0)	17.5 (17.1, 17.9)	16.6
	55 – 64	19.4 (19.0, 19.8)	22.4 (22.0, 22.8)	23.0 (22.5, 23.4)	17.2
	65 +	16.6 (16.3, 17.0)	19.6 (19.2, 20.0)	21.6 (21.2, 22.0)	21.9
Region	Northeast	13.0 (12.7, 13.3)	14.7 (14.4, 15.1)	12.2 (11.9, 12.6)	17.4[3]
	Midwest	34.9 (34.5, 35.4)	28.7 (28.3, 29.2)	33.1 (32.6, 33.6)	20.8
	South	31.8 (31.3, 32.2)	34.8 (34.3, 35.2)	34.5 (34.0, 35.0)	38.1
	West	20.3 (19.9, 20.7)	21.8 (21.4, 22.2)	20.3 (19.8, 20.7)	23.7
Choose “I don’t buy carrots”		14.0 (13.7, 14.3)	13.8 (13.5, 14.2)	14.4 (14.0, 14.8)	-
Response time (mean, seconds)		22.6 (22.0, 23.2)	24.5 (23.8, 25.2)	25.5 (24.7, 26.4)	-
Number of observations		43,279	37,229	34,932	-

Notes. The unit of the values by demographics and choosing “I don’t buy carrots” is a percentage. The response time reports the mean values whose unit is a second. The numbers in parentheses are 95 percent confidence intervals. The term, “not inferred,” in each demographics category indicates the group of respondents whose demographics are not inferred. The number of observations of the whole sample includes those under 18, and those without demographics.

[1] The data about regional groups come from 2020 Decennial Census Public Law 94-171 Redistricting Data. However, this source does not provide gender and age profiles. Instead, I

obtained gender and age group shares from the American Community Survey in 2019. The source reports estimates of the numbers of people by age group. I consider people aged 18 or more only and calculate the share of each group.
[2] I obtained the data about the American Community Survey from data.census.gov, which provides descriptive tables. There is no 18-24 age group in the source, so we used the 20-24 age group instead.
[3] Decennial Census Public Law 94-171 Redistricting Data in 2020 provides state population. I matched states with four regions and calculated the shares. Because the source does not provide population by state, the population numbers used in the calculation include people aged less than 18.

Appendix 5.D. Respondents with "I Don't Buy Carrots"

This appendix analyzes the respondents selecting the survey option "I don't buy carrots." This analysis is needed because I use this selection to separate the U.S. carrot buyers from those that do not buy carrots.

I regress whether respondents choose this option on (i) response time, (ii) whether they face a Multiple-Choice question (one if facing a Multiple-Choice question, and zero if facing a Yes-No question), (iii) female (one if female, and zero if male), (iv) age group dummies and (v) region group dummies. I use the standard linear regression with the robust standard errors (White-Huber standard errors). The previous tables (Tables 5.3, 5.4, 5.6, 5.7, 5.C.1 and 5.C.2) provide some statistics on the explanatory variables in the regression.

Table 5.D.1 reports the results of six models characterized by different subsamples and different combinations of explanatory variables. Models 1, 2, and 3 include respondents regardless of demographic information, while Models 4, 5, and 6 include only respondents with demographic information. Models 2 and 5 exclude the response time as an explanatory variable in the regressions to check whether the endogeneity of the response time variable affects the regression results. Models 3 and 6 include the response time but exclude respondents whose response time is out of the range from 5% (about 7 seconds) and 95% (about 54 seconds) to check whether outliers in the response time affect the regression results. Model 6 excludes respondents without demographic information and outliers in response time. Hence, the observation number of Model 6 is smaller than that of Model 3.

The results are: First, the WTP question type hardly affects the choice of "I don't buy carrots" (Models 1 to 6). Second, whether demographics are inferred also hardly affects the choice of "I don't buy carrots" (Models 1 to 3). Third, the inclusion of the response time variable affects results only slightly (Models 1, 2, 4, and 5). Fourth, the response time hardly affects the dependent variable in the full sample, while the impact becomes significantly negative (but small in magnitude) after excluding the outliers in terms of the response time (Models 1, 3, 4, and 6). Fifth, female respondents are less likely to choose "I don't buy carrots" than male respondents (Models 4 to 6). Sixth, compared to the 18 – 24 aged respondents, the other respondents are less likely to choose (Models 4 to 6). Seventh, the impact of the geographical location of respondents hardly affects the choice of "I don't buy carrots."

Table 5.D.2 reports the results of the additional three regression models with period dummies. Models 7, 8, and 9 correspond to Models 1, 4, and 6 in Table 5.D.1. The coefficient estimates of common variables (response time, question type, and demographics) are robust to including the period dummies. Overall, the coefficients of the period dummies are estimated to be negative. This means that the share of "I don't buy carrots" was slightly lower during the pandemic compared to before.

The regression results must not be interpreted as the determinants of carrot buyers in the U.S. retail market without further assumptions. Some respondents may randomly choose the first option simply because it seemed a quick way to get past the survey. The potential bias due to random responses is partly controlled by including the response time variable and excluding outliers in the response time.

Three groups (females, those older than 24, and respondents in the South) are less likely to select "I don't buy carrots" than other respondents. As noted earlier, this option indicates buying carrots rather than consuming carrots. To my knowledge, there is no prior analysis on the purchase patterns of carrots by gender, age, and region. But purchase relates to consumption, and Lucier and Lin (2007), who use Nielsen Homescan panel data, 1998 – 2003, describe carrot consumption by several demographics. According to their data, people in the South consume carrots more than people in the other regions, and 40 - 64-year-old people consume more than those under 40 years old. The consistency with the earlier study supports my use of responses selecting this option to focus on the U.S. carrot buyers separately from non-carrot buyers in the population.

Table 5.D.1. Determinants of the Choice of "I Don't Buy Carrots": Linear Regression Results

		Both respondents with and without demographics			Only with demographics		
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Response time (Unit: 100 seconds)		-0.0049 (0.00065)	-	-0.30 (0.0063)	-0.0053 (0.00076)	-	-0.26 (0.0073)
Face a Multiple-Choice question		0.0044 (0.0016)	0.0045 (0.0016)	-0.0022 (0.0016)	0.00097 (0.0017)	0.0010 (0.0017)	-0.0045 (0.0018)
Demographics are inferred		-0.015 (0.0015)	-0.015 (0.0015)	-0.017 (0.0016)	-	-	-
Female		-	-	-	-0.045 (0.0013)	-0.045 (0.0013)	-0.048 (0.0013)
Age	18 – 24	-	-	-	Base	Base	Base
	25 – 34	-	-	-	-0.027 (0.0030)	-0.027 (0.0030)	-0.030 (0.0031)
	35 – 44	-	-	-	-0.054 (0.0030)	-0.053 (0.0030)	-0.051 (0.0031)
	45 – 54	-	-	-	-0.068 (0.0029)	-0.068 (0.0029)	-0.058 (0.0030)
	55 – 64	-	-	-	-0.086 (0.0029)	-0.086 (0.0028)	-0.068 (0.0030)
	65+	-	-	-	-0.098 (0.0029)	-0.098 (0.0029)	-0.072 (0.0030)
Region	Northeast	-	-	-	Base	Base	Base
	Midwest	-	-	-	-0.011 (0.0022)	-0.011 (0.0022)	-0.015 (0.0022)
	South	-	-	-	0.016 (0.0022)	0.016 (0.0022)	0.015 (0.0022)
	West	-	-	-	-0.017 (0.0022)	-0.017 (0.0022)	-0.019 (0.0023)
Constant		0.16 (0.0014)	0.16 (0.0014)	0.21 (0.0020)	0.23 (0.0031)	0.23 (0.0031)	0.27 (0.0036)
R-squared		0.0005	0.0003	0.0073	0.0133	0.0131	0.0172
F-statistic		51.5	50.6	751.5	327.3	356.1	374.7
P-value		0.000	0.000	0.000	0.000	0.000	0.000
Number of observations		352,545	352,545	317,281	281,621	281,621	254,490

Notes. The dependent variable is 1 if respondents selected "I don't buy carrots," and 0, otherwise. Models have the following characteristics. Models 1, 2 and use the full sample. Models 3 and 4 include only respondents with demographics. Models 1 and 3 include the choice of "I don't buy carrots" as an explanatory variable, but Models 2 and 4 do not. The numbers in parentheses are the robust standard error (White-Huber standard error).

Table 5.D.2. Determinants of the Choice of "I Don't Buy Carrots": Linear Regression Results, Period Dummies

		Models with period dummies		
		Model 7	Model 8	Model 9
Response time (Unit: 100 seconds)		-0.0050 (0.00068)	-0.0054 (0.00076)	-0.27 (0.0073)
Face a Multiple-Choice question		0.0042 (0.0016)	0.0086 (0.0017)	-0.0047 (0.0018)
Demographics are inferred		-0.014 (0.0015)	-	-
Female		-	-0.045 (0.0013)	-0.048 (0.0013)
Age	18 – 24	-	Base	Base
	25 – 34	-	-0.027 (0.0030)	-0.030 (0.0031)
	35 – 44	-	-0.053 (0.0030)	-0.051 (0.0031)
	45 – 54	-	-0.068 (0.0029)	-0.058 (0.0030)
	55 – 64	-	-0.086 (0.0029)	-0.067 (0.0030)
	65+	-	-0.098 (0.0029)	-0.072 (0.0030)
Region	Northeast	-	Base	Base
	Midwest	-	-0.011 (0.0022)	-0.015 (0.0022)
	South	-	0.016 (0.0022)	0.015 (0.0022)
	West	-	-0.017 (0.0022)	-0.019 (0.0023)
Periods	December 2019 – January 2020	Base	Base	Base
	March – April 2020	-0.014 (0.0021)	-0.0065 (0.0024)	-0.0074 (0.0024)
	June 2020	-0.0048 (0.0022)	-0.0045 (0.0024)	-0.0062 (0.0025)
	August 2020	-0.0096 (0.0021)	-0.0056 (0.0023)	-0.0070 (0.0024)
	October 2020	-0.012 (0.0021)	-0.0061 (0.0023)	-0.010 (0.0023)
	January 2021	-0.015 (0.0021)	-0.0070 (0.0024)	-0.0079 (0.0024)
	March 2021	-0.0069 (0.0022)	0.000018 (0.0025)	-0.00060 (0.0025)

Constant	0.17 (0.0019)	0.23 (0.0034)	0.27 (0.0039)
R-squared	0.0007	0.0134	0.0173
F-statistic	25.0	212.5	243.8
P-value	0.000	0.000	0.000
Number of observations	352,545	281,621	254,490

Notes. The dependent variable is 1 if respondents selected "I don't buy carrots," and 0, otherwise. Model 7 uses the full sample. Model 8 excludes respondents without demographic information. Model 9 additionally excludes respondents whose response time is out of the range from 5% to 95%. The numbers in parentheses are the robust standard error (White-Huber standard error).

References

Adamowicz, W., P. Boxall, M. Williams, and J. Louviere. 1998. "Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation." *American Journal of Agricultural Economics* 80(1): 64-75.

Ahn, S., and J. L. Lusk. 2021. "Non-Pecuniary Effects of Sugar-Sweetened Beverage Policies." *American Journal of Agricultural Economics* 103(1): 53-69.

Alberini, A., B. Kanninen, and R. T. Carson. 1997. "Modeling Response Incentive Effects in Dichotomous Choice Contingent Valuation Data." *Land Economics* 29: 169-180.

Alfnes, F., A. G. Guttormsen, G. Steine, and K. Kolstad. 2006. "Consumers' Willingness to Pay for the Color of Salmon: A Choice Experiment with Real Economic Incentives." *American Journal of Agricultural Economics* 88(4): 1050-1061.

Ballmer-Weber, B. K., K. Skamstrup Hansen, J. Sastre, K. Andersson, I. Bätscher, J. Östling, L. Dahl, K. M. Hanschmann, T. Holzhauser, L. K. Poulsen, and J. Lidholm. 2012. "Component-Resolved in Virto Diagnosis of Carrot Allergy in Three Different Regions of Europe." *Allergy* 67(6): 758-766.

Ballmer-Weber, B. K., B. Wüthrich, A. Wangorsch, K. Fötisch, F. Altmann, and S. Vieths. 2001. "Carrot Allergy: Double-Blinded, Placebo-Controlled Food Challenge and Identification of Allergens." *Journal of Allergy and Clinical Immunology* 108(2): 301-307.

Bernard, J. C., and D. J. Bernard. 2010. "Comparing Parts with the Whole: Willingness to Pay for Pesticide-Free, Non-GM, and Organic Potatoes and Sweet Corn." *Journal of Agricultural and Resource Economics* 35(3): 457-475.

Börger T. 2016. "Are Fast Responses More Random? Testing the Effect of Response Time on Scale in an Online Choice Experiment." *Environmental Resource Economics* 65: 389-413.

Brynjolfsson, E., A. Collis, and F. Eggers. 2019. "Using Massive Online Choice Experiments to Measure Changes in Well-Being." *Proceedings of the National Academy of Sciences* 116(15): 7250-7255.

Cameron, T. A., and J. Quiggin. 1994. "Estimation Using Contingent Valuation Data from a "Dichotomous Choice with Follow-Up" Questionnaire." *Journal of Environmental Economics and Management* 27(3): 218-234.

Chang, H-H, and C. D. Meyerhoefer. 2020. "COVID-19 and the Demand for Online Food Shopping Services: Empirical Evidence from Taiwan." *American Journal of Agricultural Economics* 103(2): 448-465.

Cranfield, J. A. L. 2020. "Framing Consumer Food Demand Responses in a Viral Pandemic." *Canadian Journal of Agricultural Economics* 68: 151-156.

Crawford, S. D., M. P. Couper, and M. J. Lamias. 2001. "Web Surveys: Perceptions of Burden." *Social Science Computer Review* 19: 146-162.

Cummings, R. G., and L. O. Taylor. 1999. "Unbiased Value Estimates for Environmental Goods: A Cheap Talk Design for the Contingent Valuation Method." *American Economic Review* 89(3): 649-665.

Diamond, P. A., and J. A. Hausman. 1994. "Contingent Valuation: Is Some Number Better than No Number?" *Journal of Economic Perspectives* 8(4): 45-64.

Frederick, S., L. Lee, and E. Baskin. 2014. "The Limits of Attraction." *Journal of Marketing Research* 51(4): 487-507.

Galesic, M., and M. Bosnjak. 2009. "Effects of Questionnaire Length on Participation and Indicators of Response Quality in a Web Survey." *Public Opinion Quarterly* 73(2): 349-360.

Gao, Z., and T. Schroeder. 2009. "Effects of Label Information on Consumer Willingness-to-Pay for Food Attributes." *American Journal of Agricultural Economics* 91(3): 795-809.

Gschwandtner, A., and M. Burton. 2020. "Comparing Treatments to Reduce Hypothetical Bias in Choice Experiments Regarding Organic Food." *European Review of Agricultural Economics* 47(3): 1302-1337.

Gustafson, C. R., T. J. Lybbert, and D. A. Sumner. 2016. "Consumer Sorting and Hedonic Valuation of Wine Attributes: Exploiting Data from a Field Experiment." *Agricultural Economics* 47: 91-103.

Haaijer, R., W. Kamakura, and M. Wedel. 2000. "Response Latencies in the Analysis of Conjoint Choice Experiments." *Journal of Marketing Research* 37: 376-382.

Hanemann, W. M., J. Loomis, and B. Kanninen. 1991. "Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation." *American Journal of Agricultural Economics* 73(4): 1255-1263.

Hausman, J. A. 2012. "Contingent Valuation: From Dubious to Hopeless." *Journal of Economic Perspectives* 26(4): 43-56.

Herriges, J. A., and J. F. Shogren. 1996. "Starting Point Bias in Dichotomous Choice Valuation with Follow-Up Questioning." *Journal of Environmental Economics and Management* 30: 112-131.

Holmquist, C., J. McCluskey, and C. Ross. 2012. "Consumer Preferences and Willingness to Pau for Oak Attributes in Washington Chardonnays." *American Journal of Agricultural Economics* 94(2): 556-561.

Hulland, J., and J. Miller. 2018. "``Keep on Turkin`"? *Journal of the Academy of Marketing Science* 46: 789-794.

Jacquemet, N., R-V. Joule, S. Luchini, and J. F. Shogren. 2013. "Preference Elicitation under Oath." *Journal of Environmental Economics and Management* 65: 110-132.

Klonsky, K. 2011. "Comparison of Production Costs and Resource Use for Organic and Conventional Production Systems." *American Journal of Agricultural Economics* 94(2): 314-321.

Krystallis, A., C. Fotopoulos, and Y. Zotos. 2006. "Organic Consumers' Profile and Their Willingness to Pay (WTP) for Selected Organic Food Products in Greece." *Journal of International Consumer Marketing* 19(1): 81-106.

Lacy, K., and W. E. Huffman. 2016. "Consumer Demand for Potato Products and Willingness-to-Pay for Low-Acrylamide, Sulfite-Free Fresh Potatoes and Dices: Evidence from Lab Auctions." *Journal of Agricultural and Resource Economics* 41(1): 116-137.

Lucier, G., and B. H. Lin. 2007. *Factors Affecting Carrot Consumption in the United States*. Outlook Report. Economic Research Service, U.S. Department of Agriculture. No. VGS-31901: 1-21.

Lusk, J. L. 2003. "Effects of Cheap Talk on Consumer Willingness-to-Pay for Golden Rice." *American Journal of Agricultural Economics* 85(4): 840-856.

Lusk, J. L., M. S. Daniel, D. R. Mark, and C. L. Lusk. 2001. "Alternative Calibration and Auction Institutions for Predicting Consumer Willingness to Pay for Nongenetically Modified Corn Chips." *Journal of Agricultural and Resource Economics* 26(1): 40-57.

Malone, T., and J. L. Lusk. 2018. "A Simple Diagnostic Measure of Inattention Bias in Discrete Choice Models." *European Review of Agricultural Economics* 45(3): 455-462.

Mayen, C., M. I. Marshall, and J. Lusk. 2007. "Fresh-Cut Melon – The Money Is in the Juice." *Journal of Agricultural and Applied Economics* 39(3): 597-609.

McDonald, P., M. Mohebbi, and B. Slatkin. 2013. "Comparing Google Consumer Surveys to Existing Probability and Non-Probability Based Internet Surveys." White Paper. Available at: https://www.google.fi/insights/consumersurveys/static/consumer_surveys_whitepaper_v2.pdf. (Last accessed February 8, 2021).

Meas, T., W. Hu, M. T. Batte, T. A. Woods, and S. Ernst. 2014. "Substitutes or Complements? Consumer Preference for Local and Organic Food Attributes." *American Journal of Agricultural Economics* 97(4): 1044-1071.

Rose, J., and I. Black. 2006. "Means Matter, But Variance Matter Too: Decomposing Response Latency Influences on Variance Heterogeneity in Stated Preference Experiments." *Marketing Letters* 17: 295-310.

Scarpa, R., M. Thiene, and F. Marangon. 2008. "Using Flexible Taste Distributions to Value Collective Reputation for Environmentally Friendly Production Methods." *Canadian Journal of Agricultural Economics* 56: 145-162.

Stephens-Davidowitz, S., and H. Varian. 2015. *A Hands-On Guide to Google Data*. Working Paper. Google. Available at: http://people.ischool.berkeley.edu/~hal/Papers/2015/primer.pdf. (Last accessed February 8, 2021).

Thompson, G. D., and J. Kidwell. 1998. "Explaining the Choice of Organic Produce: Cosmetic Defects, Prices, and Consumer Preferences." *American Journal of Agricultural Economics* 80: 277-287.

U.S. Census Bureau. 2019. *2019 American Community Survey 1-Year Estimates.* Age and Sex. Available at: https://data.census.gov/cedsci/table?q=&t=Age%20and%20Sex&y=2019&tid=ACSDP1Y2019.DP05&hidePreview=true. Accessed on October 18, 2021.

U.S. Census Bureau. 2020. *2020 Census Redistricting Data (Public Law 94-171)*. Available at: https://data.census.gov/cedsci/table?q=&y=2020&d=DEC%20Redistricting%20Data%20%28PL%2094-171%29&tid=DECENNIALPL2020.P1&hidePreview=true. Accessed on October 18, 2021.

U.S. Department of Agriculture, Agricultural Marketing Service. 2020. *Retail Reports*. Custom Reports (Data Queries), Specialty Crops. Available at: https://www.ams.usda.gov/market-news/retail.

U.S. Department of Agriculture, Economic Research Service. 2020. *Vegetables and Pulses Yearbook Tables*. Available at: https://www.ers.usda.gov/data-products/vegetables-and-pulses-data/vegetables-and-pulses-yearbook-tables/. (Last accessed February 8, 2021).

U.S. Department of Agriculture, National Agricultural Statistics Service. 2020. *2019 Organic Survey*. 2017 Census of Agriculture. Vol. 3, Special Studies, Part 4. AC-17-SS-4.

Waterfield, G., S. Kaplan, and D. Zilberman. 2020. "Willingness to Pay versus Willingness to Vote: Consumer and Voter Avoidance of Genetically Modified Foods." *American Journal of Agricultural Economics*. Advanced Access. Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/ajae.12001. (Last accessed February 8, 2021).

World Bank. 2022. *Individuals Using the Internet (% of population) – United States*. World Bank Open Data. Available at:

https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=US. Accessed August 15, 2022.

Chapter 6. Estimation of the Parameters of Demand for Food Attributes Linked to Production Practices: Using Multiple-Choice Questions

This chapter provides estimates of the WTPs for two carrot attributes (organic and fresh cut) using Multiple-Choice questions. Section 6.1 reviews WTP eliciting methods. Section 6.2 describes the Multiple-Choice WTP questions. Section 6.3 presents summary statistics on the responses. Section 6.4 suggests an econometric strategy. Section 6.5 reports the estimation results. Section 6.6 concludes.

6.1. Eliciting Method

It is known that framing survey questions is important in the WTP estimations (for a review, see Carson and Groves 2007; Johnston et al. 2017). Prevalent methods to elicit willingness-to-pay include open-ended WTP statements, choice of one WTP interval given multiple intervals (Multiple-Choice questions), and a Yes or No statement given two alternatives (Ready, Buzby, and Hu. 1996; Alfnes and Rickertsen 2011; Johnston et al. 2017).

The open-ended method allows respondents to state a WTP value freely. Several authors document that many respondents report zero WTP values in open-ended questions. Zero values possibly cause a bias. Some respondents may report zero values to indicate that they do not accept or understand some aspects of hypothetical scenarios described in surveys (Ready, Buzby, and Hu 1996). Some may report when they would rather report a negative willingness to pay contradicting the researcher presumption of a positive value for all respondents and biasing estimates of parameters.

Prior work points out that using a Yes-No question (often called binary choice question) can avoid the problem of zero values (Ready, Buzby, and Hu 1996; Carson and Groves 2007). Using a Multiple-Choice question stands between the open-ended questions and the Yes-No questions in that it allows respondents to choose one interval of WTP given multiple intervals. This research uses both a Multiple-Choice question (Chapter 6) and a Yes-No question (Chapter 7).

6.2. The Willingness to Pay Question

For the Multiple-Choice question, I provided respondents with a picture of one of four realistic packages of carrots: (a) non-organic full-sized, (b) organic full-sized, (c) non-organic baby, (d) and organic baby. With a specific package on the screen, I asked respondents the following single question: *Imagine you're shopping for carrots, and you see this 1-pound package. What's the most you would be willing to pay for it?*

After first allowing the response, "I don't buy carrots," we offered respondents four payment intervals. In one iteration, we offered these four payment-intervals: *Less than $1.00, Between $1.00 and $1.49, Between $1.50 and $1.99,* and *$2.00 or more*. In another iteration of the survey, we offered a different set of payment intervals: *Less than $1.00, Between $1.00 and $1.99, Between $2.00 and $2.99,* and *$3.00 or more*.

Figure 6.1. Multiple-Choice Questions as Included in Surveys

(a) Non-organic full-sized

Imagine you're shopping for carrots, and you see this 1-pound package. What's the most you would be willing to pay for it?

I don't buy carrots

Less than $1.00

Between $1.00 and $1.99

Between $2.00 and $2.99

$3.00 or more

(b) Organic full-sized

Imagine you're shopping for carrots, and you see this 1-pound package. What's the most you would be willing to pay for it?

I don't buy carrots

Less than $1.00

Between $1.00 and $1.99

Between $2.00 and $2.99

$3.00 or more

Figure 6.1. Multiple-Choice Questions as Included in Surveys (continued)

(c) Non-organic baby

Imagine you're shopping for carrots, and you see this 1-pound package.
What's the most you would be willing to pay for it?

I don't buy carrots

Less than $1.00

Between $1.00 and $1.99

Between $2.00 and $2.99

$3.00 or more

(d) Organic baby

Imagine you're shopping for carrots, and you see this 1-pound package.
What's the most you would be willing to pay for it?

I don't buy carrots

Less than $1.00

Between $1.00 and $1.99

Between $2.00 and $2.99

$3.00 or more

Note. Respondents randomly faced either a multiple-choice question or a Yes-No question. In the group of Multiple-Choice questions, respondents randomly faced one among eight questions. Four questions are presented in this figure. The other four had different WTP intervals (Less than $1.00; Between $1.00 and $1.49; Between $1.50 and $1.99; $2.00 or more). I do not show the pictures of the other four questions here because the other features were identical. Each respondent chose one option among the five options.

6.3. Descriptive Statistics

Table 6.1 reports response shares by options from Multiple-Choice questions. The numbers in parentheses are confidence intervals for a 95% significance level. In Table 6.1, Panel A applies to the WTP intervals (Less than $1.00; Between $1.00 and $1.49; Between $1.50 and $1.99; $2.00 or more), and Panel B applies to the long WTP intervals (Less than $1.00; Between $1.00 and $1.99; Between $2.00 and $2.99; $3.00 or more). Eight Multiple-Choice questions are characterized by the two different WTP intervals and the four different carrot products.

The number of observations differs by the WTP intervals. For short WTP intervals, each question has about 8,000 observations; for long WTP intervals, each question has about 7,000 observations. The questions using short WTP intervals were distributed, and about 1,000 responses were collected in December 2019 and January 2020 (in total, about 2,000 responses), while those using long WTP intervals were distributed only in January 2020. No difference exists in the other six periods (March-April 2020, June 2020, August 2020, October 2020, January 2021, and March 2021). Hence, there are about 1,000 more observations for the questions offering the short WTP intervals than those offering the long WTP intervals.

The shares of “I don’t buy carrots” differ slightly across questions. The shares are higher when respondents were offered full-sized carrots, compared to when respondents faced fresh-cut carrots. However, the shares are similar within full-sized carrot cases (and fresh-cut carrot cases).

The option, “Less than $1.00,” is common for all the questions, so the response shares are comparable across all eight questions. The shares are smaller in the respondents offered organic carrots than those offered non-organic carrots. The difference in the WTP intervals affects the shares only slightly. Also, the shares are little affected by whether respondents were offered full-sized carrots or fresh-cut carrots.

The responses to other options differ between the short and long WTP intervals. However, the response shares between the short and long WTP intervals are comparable in two ways. First, the sum of the shares of the two options, “Between $1.00 and $1.49” and “Between $1.50 and $1.99,” in the short WTP intervals is comparable to the share of the option, “Between $1.00 and $1.99” in the long WTP intervals. In this comparison, the sum of the two options in the short WTP intervals is bigger than the corresponding shares in the long WTP intervals. Second, the share of the option, “$2.00 or more,” in the short WTP intervals is comparable to the sum of the shares of the two options, “Between $2.00 and $2.99” and “$3.00 or more,” in the long WTP intervals. In this comparison, the sum of the shares for two options in the long WTP intervals is higher than the comparable share in the case with short WTP intervals. We will discuss the impact of different WTP intervals on the regression results in Table 6.8.

The response shares provide information similar to a demand function for each carrot product. Figure 6.2 indicates the accumulated response shares along maximum WTP values for individual carrot packages. Panel A is for the short WTP intervals with the three evaluation points of accumulated response shares ($1.00, $1.50, and $2.00). Panel B is for the long WTP intervals with the three evaluation points ($1.00, $2.00, and $3.00). Each panel has four piecewise linear lines by the four carrot products: non-organic full-sized (the square mark), organic full-sized (the triangular mark), non-organic fresh-cut (the circle mark), and organic fresh-cut (the diamond mark). The response shares are calculated based on Table 6.1.

Let us compare organic lines and non-organic lines. In Panel A, the organic full-sized line is further away from the vertical axis than the non-organic full-sized line. A similar pattern exists between the organic fresh-cut line and the non-organic fresh-cut line. Panel B also shows a similar pattern. These results indicate a positive WTP premium of organic carrots over conventional ones.

Next, let us compare fresh-cut lines and full-sized lines. Panel A shows that the non-organic full-sized line is further away from the vertical axis than the non-organic fresh-cut line. A similar pattern exists between the organic full-sized line and the organic fresh-cut line. We can find a similar pattern in Panel B. These results indicate that consumers are unwilling to pay extra for fresh-cut carrots over full-sized carrots. This indication is inconsistent with the retail price premium of fresh-cut carrots over full-sized carrots (Table 5.2, Chapter 5).

In Multiple-Choice questions, respondents faced one product without alternatives. Lines in Figure 6.2 are close together, implying that showing products separately does not elicit WTPs for differences in products.

I interpret the lines in Figure 6.2 as approximates to demand functions, using piecewise linear functions. Given this interpretation, the piecewise lines indicate that respondents are very elastic to offered prices above a dollar. For example, in Panel A (the short WTP interval case), the response share of non-organic full-sized carrots falls by about 60% as its price rises by 33%, using the point at $1.50 per pound as an evaluation point, implying its price elasticity is about -2. Similar elasticity values can be found for other carrot packages and panels. Elastic demand functions imply that respondents were aware that non-organic full-sized carrots are priced around $1.00 per pound and other carrots, including organic carrots and fresh-cut carrots, are also priced frequently less than $2.00 per pound.

Table 6.2 reports the WTP question response shares from the sample only with demographics, comparable to Table 6.1 (the full sample). Overall, the response shares are similar between the full sample (Table 6.1) and the subsample only with demographics (Table 6.2).

Although the shares of "Less than $1.00" are slightly smaller in Table 6.2 than in Table 6.1, the 95% confidence intervals overlap. In Table 6.5, Section 6.5, I will examine whether the exclusion of respondents without demographics affects the regression results.

Tables 6.3 and 6.4 report the response shares before and during COVID-19. Table 6.3 is for the short WTP intervals, while Table 6.4 is for the long WTP intervals. The 95% confidence intervals of the response shares overlap between the periods before and during the pandemic. I will discuss the impact of COVID-19 again in the next section where an interval regression is conducted after controlling respondent demographics and other survey environment features.

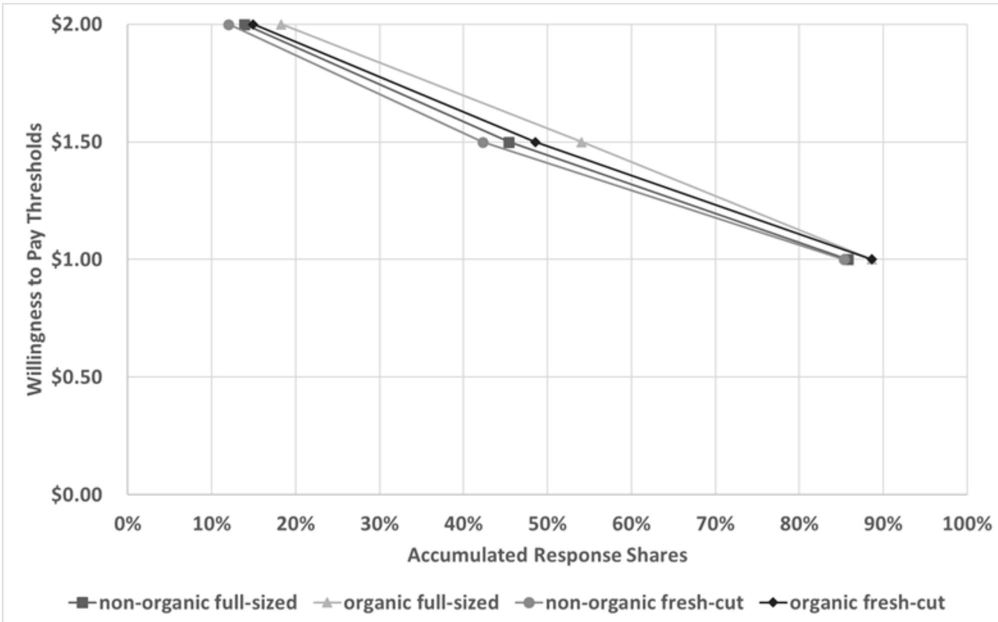
Table 6.1. Summary Statistics, Responses from Multiple-Choice Questions

	Full-sized		Fresh cut	
	Non-organic	Organic	Non-organic	Organic
	%	%	%	%
Panel A. Short WTP intervals				
I don't buy carrots	15.6 (14.8, 16.4)	16.3 (15.5, 17.1)	14.1 (13.4, 14.9)	14.2 (13.5, 15.0)
Less than $1.00	12.0 (11.3, 12.8)	9.5 (8.8, 10.1)	12.6 (11.9, 13.3)	9.7 (9.1, 10.4)
Between $1.00 and $1.49	34.1 (33.1, 35.2)	29.0 (28.0, 30.0)	37.0 (35.9, 38.0)	34.4 (33.4, 35.5)
Between $1.50 and $1.99	26.6 (25.6, 27.5)	30.0 (29.1, 31.1)	26.0 (25.1, 27.0)	28.8 (27.8, 29.8)
$2.00 or more	11.7 (11.0, 12.4)	15.3 (14.5, 16.1)	10.3 (9.6, 11.0)	12.8 (12.1, 13.6)
Number of observations	8,014	8,010	8,011	8,029
Panel B. Long WTP intervals				
I don't buy carrots	15.3 (14.4, 16.1)	15.9 (15.1, 16.8)	13.0 (12.3, 13.8)	14.6 (13.8, 15.5)
Less than $1.00	13.4 (12.6, 14.2)	11.0 (10.3, 11.7)	13.9 (13.1, 14.7)	10.9 (10.2, 11.7)
Between $1.00 and $1.99	46.7 (45.5, 47.8)	41.1 (40.0, 42.3)	49.2 (48.0, 50.3)	45.4 (44.3, 46.6)
Between $2.00 and $2.99	19.9 (18.9, 20.8)	25.0 (24.0, 26.0)	19.0 (18.1, 20.0)	23.7 (22.7, 24.7)
$3.00 or more	4.8 (4.3, 5.3)	7.0 (6.4, 7.6)	4.9 (4.4, 5.4)	5.3 (4.8, 5.8)
Number of observations	7,006	7,010	7,008	7,008

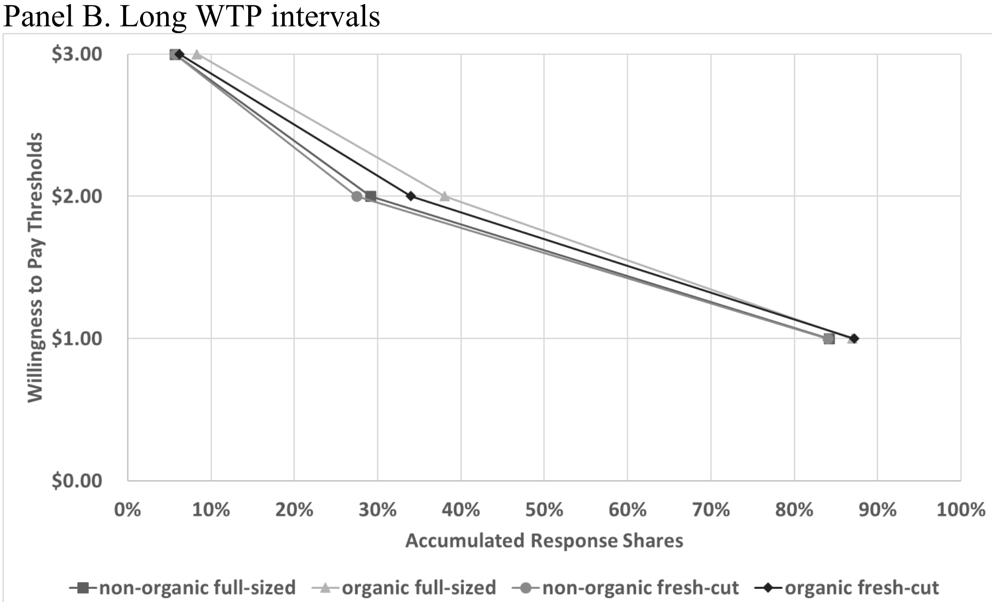
Notes: This table reports response shares by options. The numbers in parentheses are confidence intervals under a 95% significance level Panel A is for the responses from the questions using short WTP intervals. Panel B is for those from the questions using long WTP intervals.

Figure 6.2. Accumulated Response Shares by Four Carrot Packages

Panel A. Short WTP intervals



Panel B. Long WTP intervals



Notes. This figure indicates the accumulated response shares by the three thresholds characterized by each WTP interval. Panel A is for the short WTP intervals with the three thresholds ($1.00, $1.50, and $2.00). Panel B is for the long WTP intervals with the three thresholds ($1.00, $2.00, and $3.00). Each panel has four piecewise linear lines by the four carrot products: non-organic full-sized (the square mark), organic full-sized (the triangular mark), non-organic fresh-cut (the circle mark), and organic fresh-cut (the diamond mark). The response shares are calculated based on Table 6.1.

Table 6.2. Summary Statistics, Responses from Multiple-Choice Questions: A Subsample only with Demographics

	Full-sized		Fresh cut	
	Non-organic	Organic	Non-organic	Organic
	%	%	%	%
Panel A. Short WTP intervals				
I don't buy carrots	15.0 (14.1, 15.9)	15.6 (14.7, 16.5)	13.7 (12.9, 14.6)	13.8 (13.0, 14.7)
Less than $1.00	11.4 (10.7, 12.2)	9.1 (8.5, 9.9)	12.4 (11.6, 13.3)	9.3 (8.6, 10.1)
Between $1.00 and $1.49	34.7 (33.5, 35.8)	29.1 (28.0, 30.2)	37.3 (36.1, 38.5)	34.7 (33.6, 35.9)
Between $1.50 and $1.99	27.2 (26.1, 28.3)	30.6 (29.5, 31.7)	26.4 (25.3, 27.5)	29.0 (27.9, 30.1)
$2.00 or more	11.7 (11.0, 12.5)	15.6 (14.7, 16.5)	10.2 (9.5, 10.9)	13.1 (12.3, 14.0)
Number of observations	6,536	6,415	6,468	6,181
Panel B. Long WTP intervals				
I don't buy carrots	14.9 (14.0, 15.8)	15.3 (14.4, 16.2)	12.4 (11.6, 13.3)	14.2 (13.3, 15.2)
Less than $1.00	13.1 (12.2, 14.0)	10.7 (9.9, 11.5)	13.9 (13.0, 14.8)	10.5 (9.7, 11.3)
Between $1.00 and $1.99	46.7 (45.4, 48.1)	42.0 (40.7, 43.3)	50.0 (48.7, 51.3)	45.9 (44.6, 47.2)
Between $2.00 and $2.99	20.5 (19.4, 21.6)	25.3 (24.1, 26.4)	19.1 (18.1, 20.2)	24.3 (23.1, 25.4)
$3.00 or more	4.8 (4.3, 5.4)	6.8 (6.1, 7.4)	4.6 (4.1, 5.2)	5.2 (4.6, 5.8)
Number of observations	5,529	5,671	5,505	5,620

Notes: This table reports response shares by options. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the responses from the questions using short WTP intervals. Panel B is for those from the questions using long WTP intervals.

Table 6.3. Summary Statistics, Responses from Multiple-Choice Questions, Short WTP Intervals, by before and during COVID-19

	Full-sized		Fresh cut	
	Non-organic	Organic	Non-organic	Organic
	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)				
I don't buy carrots	17.3 (15.7, 19.0)	16.7 (15.2, 18.4)	14.5 (13.0, 16.1)	15.0 (13.6, 16.7)
Less than $1.00	12.6 (11.2, 14.1)	10.1 (8.9, 11.5)	13.3 (11.9, 14.9)	10.1 (8.9, 11.5)
Between $1.00 and $1.49	32.5 (30.5, 34.6)	29.9 (27.9, 31.9)	36.5 (34.4, 38.6)	33.2 (31.2, 35.3)
Between $1.50 and $1.99	26.2 (24.3, 28.2)	28.9 (27.0, 30.9)	25.8 (24.0, 27.8)	28.2 (26.3, 30.2)
$2.00 or more	11.4 (10.1, 12.9)	14.3 (12.9, 15.9)	9.8 (8.6, 11.2)	13.4 (11.9, 14.9)
Number of observations	2,010	2,003	2,004	2,020
Panel B. During COVID-19 (March 2020 – March 2021)				
I don't buy carrots	15.0 (14.1, 15.9)	16.1 (15.2, 17.0)	14.0 (13.1, 14.9)	14.0 (13.1, 14.9)
Less than $1.00	11.8 (11.0, 12.7)	9.2 (8.5, 10.0)	12.4 (11.5, 13.2)	9.6 (8.8, 10.3)
Between $1.00 and $1.49	34.7 (33.5, 35.9)	28.6 (27.5, 29.8)	37.1 (35.9, 38.4)	34.8 (33.7, 36.1)
Between $1.50 and $1.99	26.7 (25.6, 27.8)	30.4 (29.3, 31.6)	26.1 (25.0, 27.2)	29.0 (27.8, 30.1)
$2.00 or more	11.8 (11.0, 12.7)	15.6 (14.7, 16.5)	10.4 (9.7, 11.2)	12.7 (11.8, 13.5)
Number of observations	6,004	6,007	6,007	6,009

Notes: This table reports response shares by options. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the period before COVID-19. Panel B is for the periods during COVID-19.

Table 6.4. Summary Statistics, Responses from Multiple-Choice Questions, Long WTP Intervals, by before and during COVID-19

	Full-sized		Fresh cut	
	Non-organic	Organic	Non-organic	Organic
	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)				
I don't buy carrots	17.0 (14.8, 19.4)	17.8 (15.6, 20.3)	14.9 (12.8, 17.2)	16.2 (14.0, 18.6)
Less than $1.00	13.9 (11.9, 16.2)	13.7 (11.7, 16.0)	14.1 (12.0, 16.4)	11.6 (9.7, 13.7)
Between $1.00 and $1.99	46.5 (43.4, 49.6)	38.9 (36.0, 42.0)	47.2 (44.1, 50.3)	46.5 (43.4, 49.6)
Between $2.00 and $2.99	17.3 (15.1, 19.8)	22.5 (20.0, 25.2)	18.1 (15.9, 20.7)	20.8 (18.4, 23.4)
$3.00 or more	5.4 (4.2, 7.0)	7.0 (5.6, 8.7)	5.8 (4.5, 7.4)	5.0 (3.8, 6.5)
Number of observations	1,001	1,004	1,003	1,002
Panel B. During COVID-19 (March 2020 – March 2021)				
I don't buy carrots	15.0 (14.1, 15.9)	15.6 (14.7, 16.6)	12.7 (11.9, 13.6)	14.4 (13.5, 15.3)
Less than $1.00	13.3 (12.5, 14.2)	10.5 (9.8, 11.3)	13.9 (13.0, 14.8)	10.8 (10.1, 11.6)
Between $1.00 and $1.99	46.7 (45.5, 48.0)	41.5 (40.2, 42.7)	49.5 (48.2, 50.8)	45.3 (44.0, 46.5)
Between $2.00 and $2.99	20.3 (19.3, 21.3)	25.4 (24.3, 26.5)	19.2 (18.2, 20.2)	24.2 (23.2, 25.3)
$3.00 or more	4.7 (4.2, 5.3)	70.1 (63.9, 76.8)	4.7 (4.2, 5.3)	5.3 (4.8, 5.9)
Number of observations	6,005	6,006	6,005	6,006

Notes: This table reports response shares by options. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the period before COVID-19. Panel B is for the periods during COVID-19.

6.4. Econometric Strategy

For econometric analysis of the responses to Multiple-Choice questions, I use an interval regression (Davidson and MacKinnon 2004, sec 11.6). The paper written by Cameron and Huppert (1989) is an early study in resource economics using an interval regression. Recent examples related to food include the study by Waterfield, Kaplan, and Zilberman (2020).

I specify the log of WTP of jth respondent for a carrot product as follows:

$$Y_j = b_0 + b_1 Org_j + b_2 Fresh_j + b_3 x_j + u_j. \tag{6.1}$$

The error term, u_j, is assumed to be normally distributed, i.e., $u_j \sim N(0, \sigma^2)$ for all j. I use a lognormal distribution on the WTP because the distribution of WTPs is skewed (Table 6.1). The term Org_j is one if jth respondent was offered a choice among organic carrots, otherwise zero. The term $Fresh_j$ is one if jth respondent was offered a choice among fresh-cut carrots, otherwise zero. The term x_j is a vector of explanatory variables including demographics and other survey environment features, which will be listed below. The terms b are coefficients of the corresponding explanatory variables.

Note jth respondent reports a WTP interval including Y_j rather than directly reporting Y_j. Hence, I use the following regression model:

$$y_j = b_0 + b_1 Org_j + b_2 Fresh_j + b_3 x_j + u_j. \tag{6.2}$$

The dependent variable is a discrete variable defined as follows:

$$y_j = \begin{cases} 1 & \text{if } Y_j < t_1 \\ 2 & \text{if } t_1 \leq Y_j < t_2 \\ 3 & \text{if } t_2 \leq Y_j < t_3 \\ 4 & \text{if } Y_j \geq t_3 \end{cases}.$$

The terms t_1, t_2, t_3, and t_4 are thresholds of WTP intervals. The values of the dependent variable indicate four respondent groups. The first group, denoted by I_1, includes respondents whose

WTP is in less than y_1. The likelihood for these observations is $\Pr(Y_j < t_1)$. The second group, denoted by I_2, includes the respondents whose WTP is in the interval $t_1 \leq Y_j < t_2$. For these observations, the likelihood is $\Pr(t_1 \leq Y_j \leq t_2)$. The third group, denoted by I_3, is for the respondents whose WTP lies in the interval $t_2 \leq Y_j < t_3$. The likelihood is $\Pr(t_2 \leq Y_j \leq t_3)$. Finally, the fourth group, denoted by I_4, includes the respondents whose WTP is more than t_3. For these observations, the likelihood is $\Pr(Y_j \geq t_3)$.

The regression model is conducted separately by both types of WTP intervals. Recall the short intervals are: Less than \$1.00; Between \$1.00 and \$1.49; Between \$1.50 and \$1.99; \$2.00 or more. Recall the long intervals are: Less than \$1.00; Between \$1.00 and \$1.99; Between \$2.00 and \$2.99; \$3.00 or more. The thresholds depend on the WTP intervals: $t_1 = \$1.00$, $t_2 = \$1.50$, $t_3 = \$2.00$ for the short interval; $t_1 = \$1.00$, $t_2 = \$2.00$, $t_3 = \$3.00$ for the long interval.

The parameters are estimated based on the maximum likelihood method. The log-likelihood is

$$\begin{aligned} \ln L = \sum_{j \in I_1} w_j \ln \Phi\left(\frac{t_1 - Xb}{\sigma}\right) \\ + \sum_{j \in I_2} w_j \ln\left\{\Phi\left(\frac{t_2 - Xb}{\sigma}\right) - \Phi\left(\frac{t_1 - Xb}{\sigma}\right)\right\} \\ + \sum_{j \in I_3} w_j \ln\left\{\Phi\left(\frac{t_3 - Xb}{\sigma}\right) - \Phi\left(\frac{t_2 - Xb}{\sigma}\right)\right\} \\ + \sum_{j \in I_4} w_j \ln\left\{1 - \Phi\left(\frac{t_3 - Xb}{\sigma}\right)\right\} \end{aligned} \tag{6.3}$$

where the function $\Phi(\cdot)$ is the cumulative standard normal distribution; w_j is the weight for the jth respondent response; The term X is the vector of all the explanatory variables in the regression, and the term b is the vector of the corresponding coefficients. I use the inverse of the probability that the observation is included to represent the U.S. population in demographics (gender, age, and region).

In addition to the organic dummy, Org_j, and the fresh-cut dummy, $Fresh_j$, the following explanatory variables are included in the regressions. The value of the female dummy is one if respondents are female, and it is zero if they are male. Six age groups are included: 18 – 24 (base), 25 – 34, 35 – 44, 45 – 54, 55 – 64, and 65+. Four regions are considered: Northeast (base), Midwest, South, and West. The response time is a continuous variable (unit: 100 seconds). Survey periods are represented by dummy variables for the survey rounds: December 2019 – January 2020, March – April 2020, June 2020, August 2020, October 2020, January 2021, and March 2021; the base is December 2019 – January 2020. Recall descriptive statistics on demographics are presented in Tables 5.3 and 5.4 in the previous chapter.

I use the median to measure the central tendency of the WTP for carrot products. According to the features of the lognormal distribution, the median conditional on the explanatory variables is $\exp(xb)$. I calculate the median using the parameter estimates, $\hat{b}$, and the sample means of the explanatory variables, $\bar{x}$. Our specific interest in this research is the WTP for organic attribute and fresh-cut attribute, rather than the WTP for carrot products overall. The median WTP for each carrot attribute is estimated by the difference in the median WTPs for the two carrot products identical except for the attribute of interest:

$$\text{median WTP estimate of organic} = \exp\left(\hat{b}_0 + \hat{b}_1 + \hat{b}_3\bar{x}_j\right) - \exp\left(\hat{b}_0 + \hat{b}_3\bar{x}_j\right) \tag{6.4}$$

$$\text{median WTP estimate of fresh cut} = \exp\left(\hat{b}_0 + \hat{b}_2 + \hat{b}_3\bar{x}_j\right) - \exp\left(\hat{b}_0 + \hat{b}_2\bar{x}_j\right) \tag{6.5}$$

6.5. Estimation Results

In Table 6.5, the column of “full sample” reports the results, given the full sample regardless of the availability of demographics. The full sample model cannot include demographics as explanatory variables. Instead, I include a dummy variable, “demographic information is inferred,” whose value is one if respondents’ demographics are inferred and, otherwise, zero. The columns “with demographics” reports the results, given a subsample that includes only respondents whose demographics (all of the gender, age, and region) are inferred by Google Surveys. Overall, both models are significant considering the chi-squared statistics and their p-values.

The constant term represents the average WTP for carrot products offered to respondents, with the explanatory variables controlled. Both models report a positive constant estimate. This means that respondents, on average, have a positive WTP for carrot products offered in the survey.

The two models in Table 6.5 have three common explanatory variables: organic, fresh-cut, and response time. The estimates are very close to each other for all the variables. Our main interest is the coefficients of organic and fresh-cut variables. The two carrot attributes’ coefficients are little affected by the inclusion of demographics. To obtain implications for demographic effects, we will concentrate on the models using the sample that only includes respondents with demographics.

The regression model specifies a linear function of the average WTP for carrot packages, and the coefficient of each variable on the right-hand side indicates a marginal change in the average WTP for carrot packages. The coefficient for the organic dummy variable is precisely estimated to be 0.057, implying that the average WTP premium of organic over non-organic is about $0.057 per pound. The coefficient for the fresh cut dummy variable is precisely estimated to be -0.029, implying that respondents on average are not willing to pay an extra for the fresh-cut package over the full-sized package and the magnitude is about -$0.029 per pound on average.

In Table 6.5, the coefficient of the female variable is estimated to be negative, but it is not statistically significant under a 95% significance level. Also, its magnitude is close to zero. All the age dummies have a negative coefficient, with the base of 18 – 24 aged group of respondents. However, the zero-coefficient hypothesis is rejected only on the two groups, 55 – 64 and more than 64, under a 95% significance level. This means, compared to the 18 – 24 aged group, these two groups of older respondents are willing to pay less for carrot products. There are three regional dummies, Midwest, South, and West, given the base of Northeast. The coefficients of all those regional dummies are precisely estimated and negative under a 95% significance level, which implies that, compared to the Northeast, other regions' respondents are willing to pay less for carrot products.

Table 6.6 reports the estimation results of the model that includes the interaction terms between carrot attributes and demographics. For organic, the zero-parameter hypothesis is not rejected except for the interaction between the organic attribute and the South region dummy, under a 95% significance level. That coefficient is estimated to be negative, which means that respondents in the South are willing to pay less for organic than other respondents.

For fresh-cut, the zero-parameter hypothesis is not rejected except for the two interaction terms: (i) fresh cut and female, and (ii) fresh cut and 55 – 64 age group. Female respondents are willing to pay less for fresh cut than male respondents. The 55 – 64 aged respondents are willing to pay more for fresh-cut than other respondents. With these exceptions, overall, the interaction terms are not statistically significant.

Table 6.7 reports the estimation results of the model that includes period dummies and the interaction terms between carrot attributes and the period dummies. The period dummies are estimated to be positive under a 95% significance level in the three periods: March – April 2020, October 2020, and March 2021 (the base is December 2019 – January 2020). This means that respondents in the three periods were willing to pay more for carrot products faced in the survey than those in December 2019 – January 2020. Also, the coefficient values of the interaction terms are neither increasing nor decreasing, and the value is estimated to be negative in August 2020, although it is not statistically significant. The interaction terms between carrot attributes and period dummies are not statistically significant under a 95% significance level. This means that the WTPs for carrot attributes (organic and fresh cut) are robust to the effect of the pandemic.

Table 6.8 reports estimation results separately by the two WTP intervals. The column of short WTP interval is the same as the model of "With demographics" in Table 6.5. Overall, the estimation results are similar for the models with different WTP intervals. The magnitude of the organic coefficient is slightly larger in the long WTP interval model than in the short WTP interval model. In contrast, the magnitude of the fresh cut coefficient is similar between the two models.

Let me summarize the findings in Tables 6.5 to 6.8. First, the organic variable is estimated to be positive with high precision across any model specification. Second, the fresh cut variable is estimated to be negative with high precision across model specifications. Third, the results of the two carrot attributes are robust to the inclusion of demographic variables (gender, age, and region) (Tables 6.5 and 6.6). Fourth, the results of the carrot attributes are robust over periods before and during the pandemic (Table 6.7). Fifth, the organic attribute coefficient is sensitive to the difference in the WTP intervals, while the fresh-cut attribute coefficient is not (Table 6.8).

Now let us obtain the median WTPs for carrot attributes based on the estimation results. Based on the findings through various model specifications (Tables 6.5 to 6.8), I use the two models presented in Table 6.8. The two models only include the respondents whose demographics are inferred, and the variables controlled in the regression. 95% confidence intervals are calculated by a bootstrapping technique using 1,000 draws.

In Table 6.9, using the estimates from responses to the short WTP intervals, the median WTP premium of organic over non-organic is about \$0.09 per pound. The median WTP premium is about \$0.12 per pound using estimates from responses to the long WTP intervals. The 95% confidence intervals of the two median estimates do not overlap. These estimates are substantially smaller than observed market price differentials. The median WTP premium of fresh-cut products over full-sized products is about -\$0.04 per pound regardless of the WTP intervals. This negative coefficient is much smaller than the strongly positive price differential found in the market.

I will provide further discussion of potential estimation issues as well as implications of the estimation results in Chapter 7, Section 7.5.

Table 6.5. Effects of Carrot Attributes and Other Variables on WTPs: Full Sample versus Sample Only with Respondents Whose Demographics are Inferred

		Full sample	Sample with demographics	
			Not weighted	Weighted
Organic		0.054 (0.0041)	0.057 (0.0045)	0.057 (0.0048)
Fresh cut		-0.025 (0.0041)	-0.027 (0.0045)	-0.029 (0.0048)
Response time (100 seconds)		0.0032 (0.00257)	0.0035 (0.00273)	0.0038 (0.0029)
Demographic information is inferred		0.019 (0.0053)	-	-
Female		-	-0.0053 (0.00454)	-0.0065 (0.00479)
Age	18 – 24	-	Base	Base
	25 – 34	-	-0.012 (0.0094)	-0.018 (0.0100)
	35 – 44	-	-0.010 (0.0094)	-0.012 (0.0100)
	45 – 54	-	-0.0070 (0.00933)	-0.0096 (0.0099)
	55 – 64	-	-0.035 (0.00922)	-0.037 (0.0098)
	64+	-	-0.050 (0.00936)	-0.055 (0.010)
Region	Northeast	-	Base	Base
	Midwest	-	-0.060 (0.0076)	-0.062 (0.0078)
	South	-	-0.032 (0.0075)	-0.037 (0.0077)
	West	-	-0.024 (0.0081)	-0.028 (0.0083)
Constant		0.34 (0.0058)	0.42 (0.011)	0.43 (0.011)
Sigma		0.32 (0.0018)	0.31 (0.0063)	0.31 (0.0021)
Log pseudolikelihood		-34777	-27772	-27703
Chi squared		224.9	323.5	301.6
P-value		0.000	0.000	0.000
Number of observations		27,235	21,881	21,881

Notes. I use an interval regression approach. The numbers in parentheses are robust standard errors. The two models under “Only with demographics” include respondents only with demographic information. The model, “Weighted,” uses sampling weights based on demographic groups, while the model, “not weighted,” does not.

Table 6.6. Effects of Carrot Attributes and Other Variables on WTPs, with the Interactions between Carrot Attributes and Demographics

Variables		Coefficient (Standard error)	Variables		Coefficient (Standard error)
Organic		0.074 (0.020)	Response time (100 seconds)		0.0037 (0.00289)
Organic x female		0.013 (0.0096)	Female		0.0027 (0.0083)
Organic x age	18 – 24	Base	Age	18 – 24	Base
	25 – 34	-0.012 (0.020)		25 – 34	-0.021 (0.017)
	35 – 44	-0.012 (0.020)		35 – 44	-0.016 (0.017)
	45 – 54	-0.0015 (0.020)		45 – 54	-0.016 (0.016)
	55 – 64	-0.0034 (0.020)		55 – 64	-0.057 (0.016)
	64+	-0.016 (0.020)		64+	-0.060 (0.017)
Organic x region	Northeast	Base	Region	Northeast	Base
	Midwest	-0.0076 (0.016)		Midwest	-0.051 (0.013)
	South	-0.028 (0.0154)		South	-0.014 (0.013)
	West	-0.0094 (0.014)		West	-0.0094 (0.014)
Fresh cut		-0.016 (0.022)	Constant		0.41 (0.018)
Fresh cut x female		-0.031 (0.0096)	Sigma		0.31 (0.0021)
Fresh cut x age	18 – 24	Base			
	25 – 34	0.017 (0.020)	Log pseudolikelihood		-27687
	35 – 44	0.018 (0.020)	Chi squared		344.5
	45 – 54	0.014 (0.020)	P-value		0.000
	55 – 64	0.043 (0.020)	Number of observations		21,881
	64+	0.025 (0.020)			
Fresh cut x region	Northeast	Base			
	Midwest	-0.016 (0.016)			
	South	-0.020 (0.015)			
	West	-0.024 (0.018)			

Notes. I use an interval regression approach. The numbers in parentheses are robust standard errors. The model includes respondents only with demographic information. The model uses sampling weights based on demographic groups.

Table 6.7. Effects of Carrot Attributes and Other Variables on WTPs, with the Interactions between Carrot Attributes and Periods

Variables		Coefficient (Standard error)	Variables		Coefficient (Standard error)
Organic		0.064 (0.0094)	Response time (100 seconds)		0.0039 (0.0029)
Organic x Periods	Dec 2019 – Jan 2020	Base	Female		-0.0063 (0.0048)
	March – April 2020	-0.020 (0.016)	Age	18 – 24	Base
	June 2020	-0.0090 (0.016)		25 – 34	-0.019 (0.0100)
	August 2020	0.0051 (0.016)		35 – 44	-0.012 (0.010)
	October 2020	0.0017 (0.016)		45 – 54	-0.0095 (0.010)
	January 2021	-0.010 (0.017)		55 – 64	-0.036 (0.0098)
	March 2021	-0.026 (0.018)		64+	-0.055 (0.010)
Fresh cut		-0.016 (0.0094)	Region	Northeast	Base
Fresh cut x Periods	Dec 2019 – Jan 2020	Base		Midwest	-0.062 (0.0078)
	March – April 2020	-0.0046 (0.016)		South	-0.037 (0.0077)
	June 2020	-0.0043 (0.016)		West	-0.028 (0.0083)
	August 2020	-0.00062 (0.016)	Constant		0.41 (0.013)
	October 2020	-0.034 (0.0160)	Sigma		0.31 (0.0021)
	January 2021	-0.041 (0.017)			
	March 2021	-0.014 (0.018)	Log pseudolikelihood		-27683
Periods	Dec 2019 – Jan 2020	Base	Chi squared		336.5
	March – April 2020	0.036 (0.014)	P-value		0.000
	June 2020	0.017 (0.014)	Number of observations		21,881
	August 2020	-0.0054 (0.013)			
	October 2020	0.029 (0.0136)			
	January 2021	0.020 (0.015)			
	March 2021	0.044 (0.016)			

Notes. I use an interval regression approach. The numbers in parentheses are robust standard errors. The model includes respondents only with demographic information. The model uses sampling weights based on demographic groups.

Table 6.8. Effects of Carrot Attributes and Other Variables on WTPs: Short WTP Intervals versus Long WTP Intervals

		Short WTP Intervals	Long WTP Intervals
Organic		0.057 (0.0048)	0.075 (0.0070)
Fresh cut		-0.029 (0.0048)	-0.025 (0.0070)
Response time (100 seconds)		0.0038 (0.0029)	-0.00022 (0.0040)
Female		-0.0065 (0.00479)	-0.017 (0.0071)
Age	18 – 24	Base	Base
	25 – 34	-0.018 (0.0100)	-0.012 (0.015)
	35 – 44	-0.012 (0.0100)	-0.051 (0.015)
	45 – 54	-0.0096 (0.0099)	-0.044 (0.015)
	55 – 64	-0.037 (0.0098)	-0.090 (0.014)
	64+	-0.055 (0.010)	-0.12 (0.015)
Region	Northeast	Base	Base
	Midwest	-0.062 (0.0078)	-0.098 (0.011)
	South	-0.037 (0.0077)	-0.042 (0.011)
	West	-0.028 (0.0083)	-0.027 (0.012)
Constant		0.43 (0.011)	0.57 (0.016)
Sigma		0.31 (0.0021)	0.42 (0.0026)
Log pseudolikelihood		-27703	-21530
Chi squared		301.6	339.6
P-value		0.000	0.000
Number of observations		21,881	19,152

Notes. I use an interval regression approach. The numbers in parentheses are robust standard errors. The two models include respondents only with demographic information. The model uses sampling weights based on demographic groups. The column, "short WTP intervals," is for the model using the following WTP intervals: (Less than \$1.00, Between \$1.00 and \$1.49, Between \$1.50 and \$1.99, \$2.00 or more). The column, "long WTP intervals," is for the model using the other WTP intervals: (Less than \$1.00, Between \$1.00 and \$1.99, Between \$2.00 and \$2.99, \$3.00 or more).

Table 6.9. Median Willingness to Pay Estimates and Confidence Intervals

	Short WTP Intervals	Long WTP Intervals
	Median WTP (95% confidence interval)	
Organic	\$0.085 (\$0.071, \$0.099)	\$0.122 (\$0.100, \$0.144),
Fresh cut	-\$0.041 (-\$0.054, -\$0.027)	-\$0.039 (-\$0.060, -\$0.019)
Notes. The parameter estimates are from the regression models presented in Table 6.8. Confidence intervals are calculated by a bootstrapping technique using 1,000 draws.		

6.6. Summary of Findings

This chapter explores the WTP parameters of carrot attributes, using Multiple-Choice questions to elicit the demand parameters. One important finding is that the coefficient estimates of carrot attributes are robust to many different model specifications. (1) In regressions, the coefficient estimates of carrot attributes (organic and fresh cut) are robust with and without respondents whose demographics are not inferred. (2) The coefficient estimates of carrot attributes are robust with and without sampling weights by demographics. (3) The interaction terms between carrot attributes and demographics are not statistically significant. (4) The interaction terms between carrot attributes and periods are not statistically significant. (5) The organic coefficient estimate is smaller in short WTP intervals than in long WTP intervals. (6) The fresh-cut coefficient estimate is robust to selecting WTP intervals.

Other significant findings are the estimates of the WTP for carrot attributes. The median WTP premium of organic carrots over non-organic carrots is estimated to be positive (about \$0.09 per pound in the short WTP intervals and \$0.12 per pound in the long WTP intervals). Fresh-cut carrots have a lower median WTP than full-sized carrots, with the difference about -\$0.04 per pound. This is a surprising result.

In Figure 6.2, responses for each product are consistent with the expectation of a downward-sloping demand function. However, the response patterns are very close across the four products with different features in organic and fresh cut. The demand parameters of carrot attributes seem not to be elicited well when respondents are shown separate WTP questions by product type, without alternatives suggested together.

The following chapter uses Yes-No questions to estimate the carrot attribute WTPs. At the end of Chapter 7, I will summarize the findings of the two chapters, compare the findings across WTP questions and many different model specifications, and provide implications.

Appendix 6.A. Effects of Carrot Attributes and Other Variables on WTPs: Potential Effects of Outliers in the Response Time

This appendix examines whether estimation results are robust to outliers in the response time. Table 6.A.1 reports the WTP question response shares from a subsample including respondents whose response time lies within the range from 5% to 95% of the sample responses. Overall, the response shares are similar between the full sample (Table 6.1) and this subsample. Again, the shares of "Less than $1.00" are slightly smaller in this subsample than the full sample, although the 95% confidence intervals overlap.

Section 6.5 examines the coefficient estimate of the response time as an explanatory variable in regressions. Hence, we will examine whether the exclusion of outliers in the response time affects the regression results. Table 6.A.2 reports the results of three models by different samples in terms of response time: (a) not exclude in terms of response time, (b) only include respondents ranging from 1% (about 4 seconds) to 99% (about 190 seconds) in terms of response time, and (c) only include respondents ranging from 5% (about 7 seconds) to 95% (about 51 seconds) in terms of response time. The results of (a) no exclusion are the same as the "With demographics" models in Table 6.5. Overall, the estimation results are very similar across the three models. One exception is the response time variable. After excluding outliers whose response time is too short or too long, the response time variable becomes statistically significant under a 95% significance level. Also, the magnitude of that variable becomes bigger, which means that the reported WTP for carrot products increases as the response time increases so long as extreme outliers are excluded from the sample.

Table 6.A.1. Summary Statistics, Responses from Multiple-Choice Questions: A Subsample of Respondents in the Range from 5% to 95% in Response Time

	Full-sized		Fresh cut	
	Non-organic	Organic	Non-organic	Organic
	%	%	%	%
Panel A. Short WTP intervals				
I don't buy carrots	14.4 (13.6, 15.2)	15.2 (14.4, 16.0)	13.2 (12.4, 14.0)	13.1 (12.3, 13.9)
Less than $1.00	12.0 (11.3, 12.8)	9.4 (8.7, 10.1)	12.5 (11.8, 13.3)	9.5 (8.9, 10.2)
Between $1.00 and $1.49	35.1 (34.0, 36.3)	29.9 (28.8, 31.0)	38.2 (37.0, 39.3)	35.5 (34.4, 36.7)
Between $1.50 and $1.99	27.2 (26.2, 28.3)	30.6 (29.6, 31.7)	26.4 (25.4, 27.5)	29.5 (28.4, 30.5)
$2.00 or more	11.3 (10.6, 12.0)	14.9 (14.1, 15.8)	9.7 (9.0, 10.4)	12.4 (11.7, 13.2)
Number of observations	7,185	7,173	7,199	7,245
Panel B. Long WTP intervals				
I don't buy carrots	14.2 (13.4, 15.1)	14.7 (13.9, 15.6)	12.1 (11.3, 12.9)	13.5 (12.7, 14.4)
Less than $1.00	12.9 (12.1, 13.8)	10.8 (10.1, 11.6)	13.9 (13.1, 14.8)	10.9 (10.2, 11.7)
Between $1.00 and $1.99	48.0 (46.8, 49.3)	42.4 (41.2, 43.6)	50.4 (49.1, 51.6)	46.4 (45.2, 47.6)
Between $2.00 and $2.99	20.5 (19.5, 21.5)	25.4 (24.4, 26.5)	19.3 (18.3, 20.3)	24.3 (23.3, 25.4)
$3.00 or more	4.3 (3.8, 4.8)	6.6 (6.1, 7.3)	4.3 (3.8, 4.8)	4.8 (4.3, 5.3)
Number of observations	6,298	6,308	6,336	6,342

Notes: This table reports response shares by options. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the responses from the questions using short WTP intervals. Panel B is for those from the questions using long WTP intervals.

Table 6.A.2. Effects of Carrot Attributes and Other Variables on WTPs: Potential Effects of Outliers in the Response Time

		Included respondents in the distribution of the response time		
		No exclusion	From 1% to 99%	From 5% to 95%
Organic		0.057 (0.0048)	0.056 (0.0048)	0.059 (0.0049)
Fresh cut		-0.029 (0.0048)	-0.030 (0.0048)	-0.029 (0.0049)
Response time (100 seconds)		0.0038 (0.0029)	0.049 (0.015)	0.17 (0.029)
Female		-0.0065 (0.00479)	-0.0045 (0.0048)	-0.0012 (0.0049)
Age	18 – 24	Base	Base	Base
	25 – 34	-0.018 (0.0100)	-0.014 (0.010)	-0.0049 (0.010)
	35 – 44	-0.012 (0.0100)	-0.0088 (0.010)	-0.0058 (0.010)
	45 – 54	-0.0096 (0.0099)	-0.0050 (0.010)	-0.0032 (0.010)
	55 – 64	-0.037 (0.0098)	-0.034 (0.010)	-0.035 (0.010)
	64+	-0.055 (0.010)	-0.055 (0.010)	-0.059 (0.011)
Region	Northeast	Base	Base	Base
	Midwest	-0.062 (0.0078)	-0.063 (0.0078)	-0.063 (0.0080)
	South	-0.037 (0.0077)	-0.038 (0.0077)	-0.037 (0.0079)
	West	-0.028 (0.0083)	-0.028 (0.0083)	-0.030 (0.0085)
Constant		0.42 (0.011)	0.41 (0.012)	0.38 (0.013)
Sigma		0.31 (0.0063)	0.31 (0.0021)	0.30 (0.0021)
Log pseudolikelihood		-27703	-27054	-24599
Chi squared		301.6	311.0	334.8
P-value		0.000	0.000	0.000
Number of observations		21,881	21,443	19,690

Notes. I use an interval regression approach. The numbers in parentheses are robust standard errors. All three models exclude respondents without demographic information. The model uses sampling weights based on demographic groups. Three models differ in the exclusion of respondents by the response time. The column, "no exclusion," is for the model that does not exclude respondents due to the response time. The column, "from 1% to 99%," is for the model that includes respondents whose response time is in the range from 1% to 99%. The last column, “from 5% to 95%,” indicates the model including respondents whose response time ranges from 5% to 95%.

References

Alfnes, F., K. Rickertsen. 2011. "Non-Market Valuation: Experimental Methods. In J. L. Lusk, J. Roosen, and J. F. Shogren, ed. *The Oxford Handbook of the Economics of Food Consumption and Policy*. Oxford University Press, pp.215-242.

Cameron, T. A., and D. D. Huppert. 1989. "OLS versus ML Estimation of Non-Market Resource Values with Payment Card Interval Data." *Journal of Environmental Economics and Management* 17: 230-246.

Carson, R. T., and T. Groves. 2007. "Incentive and Informational Properties of Preference Questions." *Environmental and Resource Economics* 37: 181-210.

Davidson, R., and J. G. MacKinnon. *Econometric Theory and Methods*. New York: Oxford University Press.

Gustafson, C. R., T. J. Lybbert, and D. A. Sumner. 2016. "Consumer Sorting and Hedonic Valuation of Wine Attributes: Exploiting Data from a Field Experiment." *Agricultural Economics* 47: 91-103.

Johnston, R. J., K J. Boyle, W. Adamowicz, J. Bennett, R. Brouwer, T. A. Cameron, W. M. Hanemann, N. Hanley, M. Ryan, R. Carpa, R. Tourangeau, and C. A. Vossler. 2017.

Ready, R. C., J. C. Buzby, and D. Hu. 1996. "Differences between Continuous and Discrete Contingent Value Estimates." *Land Economics* 72(3): 397-411.

Waterfield, G., S. Kaplan, and D. Zilberman. 2020. "Willingness to Pay versus Willingness to Vote: Consumer and Voter Avoidance of Genetically Modified Foods." *American Journal of Agricultural Economics*. Advanced Access. Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/ajae.12001. (Last accessed February 8, 2021).

Chapter 7. Estimation of the Parameters of Demand for Food Attributes Linked to Production Practices: Using Yes-No Questions

Chapter 7 presents the WTP estimation approach and results using Yes-No questions. Compared to Multiple-Choice questions in Chapter 6, one feature of Yes-No questions is that respondents faced two comparable carrot packages at the same time, which allows respondents to consider alternatives with different carrot attributes and prices. I will describe that the Yes-No questions provide WTP estimates consistent with the observed carrot retail market.

Section 7.1 describes the WTP questions. Section 7.2 presents descriptive statistics on the responses. Section 7.3 explains the econometric strategy to estimate the WTPs for carrot attributes. Section 7.4 reports the estimation results. Section 7.5 summarizes the findings of Chapters 6 and 7 and provides implications.

7.1. Willingness to Pay Question

Respondents faced a pair of pictures of two realistic carrot packages and asked the following question: *Imagine you're shopping for carrots, and you see these two 1-pouind packages. Which package, if any, would you buy?*

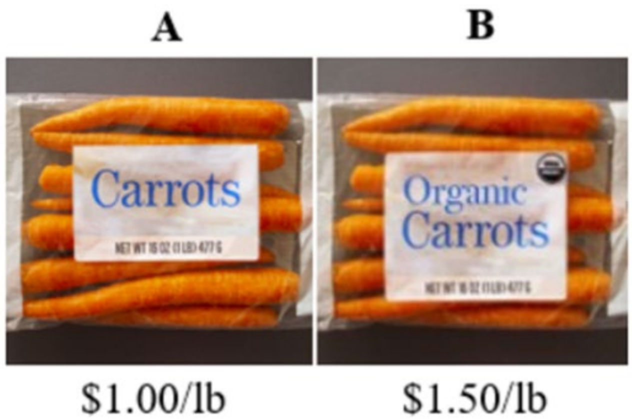
If respondents did not select the first option, "I don't buy carrots," they chose among three potential answers: *Package A for $Z, Package B for $X,* and *Neither of these packages*. The "Z" or "X" prices in the offered responses were one of three potential prices that were rotated in the surveys: $1.00, $1.50, and $2.00 per pound. These prices reflect the common range of carrot prices in the U.S. retail market. I used higher or equal prices for baby versus conventional and organic versus conventional.

The WTP questions have several important extra features. First, respondents randomly faced one pair among four pairs of carrot products. The four pairs are: (a) non-organic full-sized versus organic full-sized, (b) non-organic fresh cut versus organic fresh cut, (c) non-organic full-sized versus non-organic fresh cut, (d) organic full-sized versus organic fresh cut. Second, the position of the pictures of the carrot products within each pair (left side or right side) was randomly rotated. Figure 7.1 presents some examples of the online Yes-No questions, with the accompanying pictures.

Figure 7.1. Yes-No Questions as Included in Surveys

(a) Non-organic full-sized versus organic full-sized

Imagine you're shopping for carrots, and you see these two 1-pound packages. Which package, if any, would you buy?



I don't buy carrots

Package A for $1.00

Package B for $1.50

Neither of these packages

(b) Non-organic baby versus organic fresh cut

Imagine you're shopping for carrots, and you see these two 1-pound packages. Which package, if any, would you buy?

I don't buy carrots

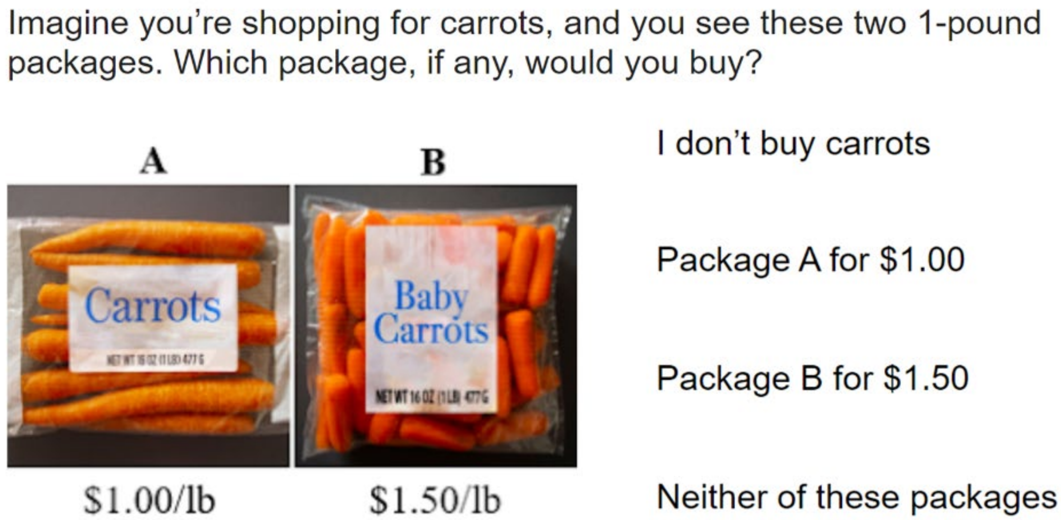
Package A for $1.00

Package B for $1.50

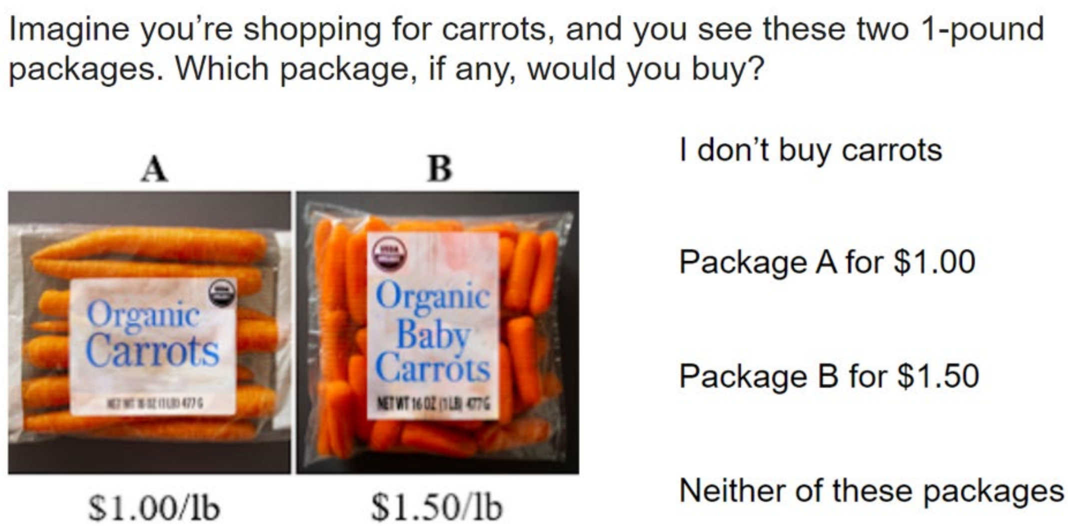
Neither of these packages

Figure 7.1. Yes-No Questions as Included in Surveys (continued)

(c) Non-organic full-sized versus non-organic fresh cut



(d) Organic full-sized versus organic fresh cut



Notes: In the respondent group of Yes-No questions, each respondent randomly faced one among 40 questions. The 40 questions are characterized by three components: (i) Four carrot pairs were considered, as seen (a), (b), (c), and (d) above. (ii) Each picture's location of a pair (A or B) was randomly determined with the same probability. (iii) Five price pairs were considered: ($1.00, $1.00), ($1.50, $1.50), ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00). When an organic product was compared with a non-organic one, the organic one was priced equally or higher than a non-organic one. Similarly, when a baby (fresh cut) product was compared with a full-sized one, the baby one was priced no less than the full-sized one. The price pairs were assigned randomly.

7.2. Descriptive Statistics

Table 7.1 reports the response shares by options chosen when respondents faced two carrot products that differ only by the organic attribute. Panel A summarizes responses from respondents who faced non-organic full-sized versus organic full-sized. Panel B summarizes responses from those who faced non-organic fresh-cut versus organic fresh-cut. The columns correspond to the five price pairs: ($1.00, $1.00), ($1.50, $1.50), ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00). The price unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019. The numbers in parentheses are confidence intervals for a 95% significance level.

Several results are noticeable in Table 7.1. First, the response shares of “I don’t buy carrots” are similar, overall, across cases, considering that the confidence intervals overlap. Second, given the same prices between organic versus non-organic, more respondents chose organic than non-organic, but a substantial share of respondents, more than 25%, chose non-organic. Third, given a $0.50 per pound or a $1.00 per pound price difference, more respondents chose non-organic than organic. Fourth, the relative share choosing organic is smaller in the $1.00 per pound price difference case than the $0.50 per pound difference case. The third and fourth results are consistent with the law of demand.

Table 7.2 summarizes responses collected for respondents who faced two products that differed only by the fresh cut (baby) attribute. Panel A reports the results collected from respondents who faced non-organic full-sized versus non-organic fresh cut. Panel B presents the results from those who faced organic full-sized versus organic fresh cut. Table 7.2 reports results by the five price pairs as did Table 7.1.

Similar results are found in Table 7.2: First, the response shares of "I don't buy carrots" are similar overall. Second, given the same prices between fresh-cut versus full-sized, more respondents chose fresh-cut carrots, although substantial respondents chose full-sized carrots. The third point is different: Given a $0.50 per pound price gap, more respondents still chose fresh-cut carrots, while, given a $1.00 per pound price gap, the response shares for fresh-cut become smaller than those for full-sized carrots. Fourth, the response shares for fresh-cut carrots are smaller in the $1.00 per pound price gap case than the $0.50 per pound price gap case, which is again consistent with the results in Table 7.1.

Tables 7.3 and 7.4 report the results only from respondents whose demographics are inferred by Google Surveys. Table 7.3 corresponds to Table 7.1, and Table 7.4 corresponds to Table 7.2 in the other aspects. Overall, the results are similar between the corresponding pairs.

Tables 7.5 to 7.8 report summary statistics by period. The period of December 2019 – January 2020 is before the pandemic. The other six periods (March 2020 to March 2021) are for periods during the pandemic. Table 7.5 includes the results of the responses when the pair of non-organic full-sized and organic full-sized was offered in surveys. Table 7.6 is for the non-organic fresh-cut and organic fresh-cut pair. Table 7.7 is for the non-organic full-sized and non-organic fresh-cut pair. Finally, Table 7.8 is for the organic full-sized and organic fresh-cut pair. Overall, the response shares are robust over periods, considering that the 95% confidence intervals of the response shares overlap before and during the pandemic.

Table 7.1. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, Full Sample

Price for organic	$1.00	$1.50	$1.50	$2.00	$2.00
Price for non-organic	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus organic full-sized					
I don't buy carrots	14.7 (14.1, 15.3)	15.3 (14.7, 15.9)	14.4 (13.8, 14.9)	13.8 (13.3, 14.4)	14.2 (13.6, 14.7)
Select the organic	47.6 (46.8, 48.5)	47.6 (46.8, 48.5)	22.5 (21.9, 23.2)	22.9 (22.3, 23.6)	18.2 (17.6, 18.8)
Select the non-organic	28.3 (27.6, 29.1)	26.6 (25.9, 27.4)	55.8 (55.0, 56.5)	55.1 (54.4, 55.9)	60.1 (59.4, 60.9)
Neither of these packages	9.4 (8.9, 9.9)	10.4 (9.9, 10.9)	7.3 (7.0, 7.8)	8.1 (7.7, 8.6)	7.5 (7.1, 7.9)
Number of observations	14,018	14,020	16,037	16,029	16,052
Panel B. Non-organic fresh cut versus organic fresh cut					
I don't buy carrots	15.0 (14.4, 15.6)	14.7 (14.1, 15.3)	13.5 (13.0, 14.1)	13.8 (13.3, 14.4)	14.0 (13.5, 14.6)
Select the organic	48.1 (47.3, 49.0)	49.2 (48.3, 50.0)	23.6 (22.9, 24.3)	23.0 (22.4, 23.8)	18.1 (17.5, 18.8)
Select the non-organic	27.7 (27.0, 28.5)	26.7 (26.0, 27.5)	55.0 (54.2, 55.8)	54.6 (53.8, 55.5)	59.5 (58.7, 60.3)
Neither of these packages	9.2 (8.7, 9.7)	9.4 (8.9, 9.9)	7.9 (7.4, 8.3)	8.5 (8.0, 9.0)	8.4 (7.9, 8.9)
Number of observations	14,026	14,023	14,019	14,015	14,028

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for organic. The numbers in parentheses are confidence intervals for a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus organic full-sized carrots. Panel B is for the case when they faced non-organic fresh-cut versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019-January 2020.

Table 7.2. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, Full Sample

Price for fresh cut	$1.00	$1.50	$1.50	$2.00	$2.00
Price for full-sized	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus non-organic fresh cut					
I don't buy carrots	13.8 (13.3, 14.4)	13.8 (13.2, 14.4)	14.6 (14.0, 15.1)	14.7 (14.2, 15.3)	15.0 (14.4, 15.5)
Select the fresh cut	53.1 (52.2, 53.9)	53.5 (52.7, 54.4)	39.6 (38.9, 40.4)	39.6 (38.8, 40.4)	32.9 (32.2, 33.6)
Select the full-sized	25.5 (24.8, 26.3)	24.7 (24.0, 25.5)	38.1 (37.3, 38.8)	37.5 (36.8, 38.3)	44.0 (43.2, 44.7)
Neither of these packages	7.6 (7.1, 8.0)	7.9 (7.5, 8.4)	7.7 (7.3, 8.2)	8.2 (7.7, 8.6)	8.2 (7.8, 8.6)
Number of observations	14,023	14,015	16,021	16,021	16,017
Panel B. Organic full-sized versus organic fresh cut					
I don't buy carrots	13.7 (13.1, 14.2)	14.3 (13.8, 14.9)	15.0 (14.5, 15.7)	14.9 (14.4, 15.5)	15.8 (15.2, 16.4)
Select the fresh cut	53.8 (53.0, 54.6)	52.2 (51.4, 53.1)	39.2 (38.3, 40.0)	37.4 (36.6, 38.2)	31.4 (30.6, 32.2)
Select the full-sized	22.7 (22.0, 23.4)	22.6 (21.9, 23.3)	35.5 (34.7, 36.3)	35.6 (34.9, 36.4)	40.8 (40.0, 41.6)
Neither of these packages	9.8 (9.3, 10.3)	10.9 (10.4, 11.4)	10.3 (9.8, 10.8)	12.0 (11.5, 12.6)	12.0 (11.5, 12.5)
Number of observations	14,020	14,027	14,014	14,014	14,010

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for fresh cut. The numbers in parentheses are confidence intervals for a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus non-organic fresh-cut carrots. Panel B is for the case when they faced organic full-sized versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.3. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, Only Respondents with Demographics

Price for organic	$1.00	$1.50	$1.50	$2.00	$2.00
Price for non-organic	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus organic full-sized					
I don't buy carrots	14.2 (13.6, 14.9)	15.0 (14.4, 15.7)	13.9 (13.3, 14.5)	13.4 (12.8, 13.9)	14.1 (13.5, 14.7)
Select the organic	48.1 (47.2, 49.0)	48.0 (47.1, 49.0)	22.5 (21.8, 23.3)	23.1 (22.4, 23.9)	18.1 (17.5, 18.8)
Select the non-organic	28.3 (27.6, 29.1)	27.0 (26.2, 27.8)	56.4 (55.6, 57.3)	55.6 (54.7, 56.4)	60.4 (59.5, 61.2)
Neither of these packages	9.1 (8.5, 9.6)	9.9 (9.4, 10.5)	7.2 (6.7, 7.6)	7.9 (7.5, 8.4)	7.4 (6.9, 7.8)
Number of observations	11,373	11,032	12,959	13,016	12,884
Panel B. Non-organic fresh cut versus organic fresh cut					
I don't buy carrots	14.6 (14.0, 15.3)	14.4 (13.8, 15.1)	13.0 (12.4, 13.6)	13.7 (13.0, 14.3)	13.8 (13.2, 14.4)
Select the organic	48.4 (47.5, 49.3)	49.5 (48.6, 50.4)	23.8 (23.0, 24.6)	23.3 (22.5, 24.1)	18.2 (17.5, 18.9)
Select the non-organic	28.0 (27.2, 28.9)	27.0 (26.2, 27.9)	55.6 (54.7, 56.5)	55.0 (54.1, 55.9)	60.0 (59.0, 60.9)
Neither of these packages	8.9 (8.4, 9.5)	9.1 (8.6, 9.6)	7.6 (7.2, 8.1)	8.0 (7.5, 8.5)	8.1 (7.6, 8.6)
Number of observations	11,256	11,311	11,101	11,407	11,339

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for organic. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus organic full-sized carrots. Panel B is for the case when they faced non-organic fresh-cut versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.4. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, Only Respondents with Demographics

Price for fresh cut	$1.00	$1.50	$1.50	$2.00	$2.00
Price for full-sized	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus non-organic fresh cut					
I don't buy carrots	13.7 (13.1, 14.4)	13.7 (13.0, 14.3)	14.3 (13.7, 14.9)	14.5 (13.9, 15.1)	15.0 (14.4, 15.7)
Select the fresh cut	53.6 (52.7, 54.6)	53.9 (53.0, 54.8)	40.1 (39.2, 40.9)	40.1 (39.3, 41.0)	33.5 (32.7, 34.3)
Select the full-sized	25.3 (24.5, 26.1)	24.8 (24.0, 25.6)	38.3 (37.5, 39.2)	37.6 (36.7, 38.4)	43.7 (42.9, 44.6)
Neither of these packages	7.3 (6.8, 7.8)	7.6 (7.2, 8.1)	7.3 (6.9, 7.8)	7.8 (7.4, 8.3)	7.7 (7.3, 8.2)
Number of observations	11,239	11,134	12,672	12,894	12,585
Panel B. Organic full-sized versus organic fresh cut					
I don't buy carrots	13.5 (12.9, 14.2)	14.2 (13.5, 14.8)	14.6 (14.0, 15.3)	14.8 (14.2, 15.5)	15.7 (15.1, 16.4)
Select the fresh cut	54.5 (53.6, 55.4)	52.9 (52.0, 53.8)	40.0 (39.1, 40.9)	37.7 (36.8, 38.6)	31.7 (30.9, 32.6)
Select the full-sized	22.5 (21.7, 23.3)	22.4 (21.6, 23.2)	35.4 (34.6, 36.3)	35.9 (35.0, 36.8)	41.0 (40.1, 41.9)
Neither of these packages	9.5 (9.0, 10.0)	10.6 (10.0, 11.2)	10.0 (9.4, 10.5)	11.6 (11.0, 12.2)	11.5 (10.9, 12.1)
Number of observations	11,128	11,127	11,143	10,992	11,104

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for fresh cut. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus non-organic fresh-cut carrots. Panel B is for the case when they faced organic full-sized versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.5. Summary Statistics, Responses from Yes-No Questions, Non-Organic Full-Sized versus Organic Full-Sized, before and during COVID-19

Price for organic	$1.00	$1.50	$1.50	$2.00	$2.00
Price for non-organic	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)					
I don't buy carrots	15.7 (14.2, 17.4)	16.0 (14.5, 17.7)	14.9 (13.9, 16.1)	14.6 (13.5, 15.7)	14.7 (13.6, 15.8)
Select the organic	46.4 (44.3, 48.6)	47.0 (44.8, 49.2)	22.2 (38.9, 40.4)	23.0 (21.7, 24.3)	17.8 (16.6, 19.0)
Select the non-organic	28.7 (26.8, 30.8)	26.6 (24.7, 28.6)	56.1 (54.6, 57.7)	54.2 (52.7, 55.8)	60.1 (58.5, 61.6)
Neither of these packages	9.1 (7.9, 10.5)	10.4 (9.1, 11.8)	6.7 (5.9, 7.5)	8.2 (7.4, 9.1)	7.4 (6.7, 8.3)
Number of observations	2,007	2,006	4,027	4,016	4,041
Panel B. During COVID-19 (March 2020 – March 2021)					
I don't buy carrots	14.5 (13.9, 15.1)	15.2 (14.6, 15.9)	14.2 (13.6, 14.8)	13.6 (13.0, 14.2)	14.0 (13.4, 14.6)
Select the organic	47.8 (46.9, 48.7)	47.8 (46.9, 48.6)	22.6 (21.9, 23.4)	22.9 (22.1, 23.6)	18.3 (17.6, 19.0)
Select the non-organic	28.2 (27.4, 29.0)	26.6 (25.9, 27.4)	55.6 (54.7, 56.5)	55.4 (54.5, 56.3)	60.2 (59.3, 61.0)
Neither of these packages	9.4 (8.9, 10.0)	10.4 (9.9, 10.9)	7.6 (7.1, 8.1)	8.1 (7.6, 8.6)	7.5 (7.1, 8.0)
Number of observations	12,011	12,014	12,010	12,013	12,011

Notes: This table reports the response shares by options when respondents faced non-organic full-sized versus organic full-sized carrots. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the periods before COVID-19. Panel B is for the periods during COVID-19. The five columns are price pairs that respondents faced, and the unit is dollars per pound. In Panel A, three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.6. Summary Statistics, Responses from Yes-No Questions, Non-Organic Fresh-Cut versus Organic Fresh-Cut, before and during COVID-19

Price for organic	$1.00	$1.50	$1.50	$2.00	$2.00
Price for non-organic	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)					
I don't buy carrots	16.5 (14.9, 18.1)	14.8 (13.4, 16.5)	14.5 (13.0, 16.1)	15.4 (13.9, 17.1)	16.6 (15.0, 18.3)
Select the organic	47.4 (45.2, 49.6)	47.4 (45.2, 49.6)	23.2 (21.4, 25.1)	23.1 (21.3, 25.0)	17.5 (15.9, 19.2)
Select the non-organic	27.9 (26.0, 30.0)	28.1 (26.2, 30.1)	53.7 (51.6, 55.9)	52.1 (49.9, 54.3)	57.0 (54.8, 59.1)
Neither of these packages	8.3 (7.1, 9.5)	9.6 (8.4, 11.0)	8.5 (7.4, 9.8)	9.4 (8.2, 10.7)	8.9 (7.8, 10.3)
Number of observations	2,011	2,014	2,004	2,005	2,006
Panel B. During COVID-19 (March 2020 – March 2021)					
I don't buy carrots	15.0 (14.4, 15.6)	14.7 (14.1, 15.3)	13.5 (13.0, 14.1)	13.8 (13.3, 14.4)	14.0 (13.5, 14.6)
Select the organic	48.1 (47.3, 49.0)	49.2 (48.3, 50.0)	23.6 (22.9, 24.3)	23.0 (22.4, 23.8)	18.1 (17.5, 18.8)
Select the non-organic	27.7 (27.0, 28.5)	26.7 (26.0, 27.5)	55.0 (54.2, 55.8)	54.6 (53.8, 55.5)	59.5 (58.7, 60.3)
Neither of these packages	9.2 (8.7, 9.7)	9.4 (8.9, 9.9)	7.9 (7.4, 8.3)	8.5 (8.0, 9.0)	8.4 (7.9, 8.9)
Number of observations	14,026	14,023	14,019	14,015	14,028

Notes: This table reports the response shares by options when respondents faced non-organic fresh-cut versus organic fresh-cut carrots. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the periods before COVID-19. Panel B is for the periods during COVID-19. The five columns are price pairs that respondents faced, and the unit is dollars per pound.

Table 7.7. Summary Statistics, Responses from Yes-No Questions, Non-Organic Full-Sized versus Non-Organic Fresh-Cut, before and during COVID-19

Price for fresh cut	$1.00	$1.50	$1.50	$2.00	$2.00
Price for full-sized	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)					
I don't buy carrots	15.1 (13.6, 16.7)	14.0 (12.6, 15.6)	14.6 (13.6, 15.7)	15.6 (14.5, 16.8)	15.6 (14.5, 16.8)
Select the fresh cut	52.8 (50.6, 55.0)	55.2 (53.0, 57.3)	39.9 (38.4, 41.4)	40.1 (38.6, 41.6)	33.6 (32.2, 35.1)
Select the full-sized	24.9 (23.0, 26.8)	24.1 (22.2, 26.0)	37.5 (36.0, 39.0)	36.3 (34.8, 37.8)	42.8 (41.3, 44.4)
Neither of these packages	7.2 (6.2, 8.4)	6.7 (5.7, 7.9)	8.0 (7.2, 8.9)	8.0 (7.2, 8.9)	7.9 (7.1, 8.8)
Number of observations	2,007	2,003	4,010	4,009	4,005
Panel B. During COVID-19 (March 2020 – March 2021)					
I don't buy carrots	13.6 (13.0, 14.3)	13.7 (13.1, 14.4)	14.5 (13.9, 15.2)	14.4 (13.8, 15.1)	14.7 (14.1, 15.4)
Select the fresh cut	53.1 (52.2, 54.0)	53.3 (52.4, 54.2)	39.5 (38.7, 40.4)	39.4 (38.5, 40.3)	32.7 (31.8, 33.5)
Select the full-sized	25.6 (24.9, 26.4)	24.9 (24.1, 25.6)	38.3 (37.4, 39.2)	38.0 (37.1, 38.8)	44.3 (43.5, 45.2)
Neither of these packages	7.6 (7.2, 8.1)	8.1 (7.7, 8.6)	7.7 (7.2, 8.1)	8.2 (7.7, 8.7)	8.3 (7.8, 8.8)
Number of observations	12,016	12,012	12,011	12,012	12,012

Notes: This table reports the response shares by options when respondents faced non-organic full-sized versus non-organic fresh-cut carrots. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the periods before COVID-19. Panel B is for the periods during COVID-19. The five columns are price pairs that respondents faced, and the unit is dollars per pound. In Panel A, three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.8. Summary Statistics, Responses from Yes-No Questions, Organic Full-Sized versus Organic Fresh-Cut, before and during COVID-19

Price for fresh cut	$1.00	$1.50	$1.50	$2.00	$2.00
Price for full-sized	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Before COVID-19 (December 2019 – January 2020)					
I don't buy carrots	14.1 (12.7, 15.7)	14.3 (12.8, 15.9)	16.3 (14.7, 18.0)	14.7 (13.2, 16.3)	18.0 (16.4, 19.7)
Select the fresh cut	54.5 (52.3, 56.7)	53.0 (50.8, 55.2)	40.3 (38.2, 42.5)	40.0 (37.9, 42.1)	32.1 (30.0, 34.1)
Select the full-sized	21.8 (20.1, 23.7)	21.4 (19.7, 23.3)	34.0 (31.9, 36.0)	33.1 (31.1, 35.2)	39.0 (36.9, 41.2)
Neither of these packages	9.5 (8.3, 10.9)	11.3 (10.0, 12.7)	9.4 (8.2, 10.8)	12.2 (10.9, 13.8)	10.9 (9.6, 12.4)
Number of observations	2,003	2,011	2,001	2,001	2,003
Panel B. During COVID-19 (March 2020 – March 2021)					
I don't buy carrots	13.6 (13.0, 14.2)	14.3 (13.7, 15.0)	14.8 (14.2, 15.5)	15.0 (14.3, 15.6)	15.4 (14.8, 16.1)
Select the fresh cut	53.7 (52.8, 54.6)	52.1 (51.2, 53.0)	39.0 (38.1, 39.8)	37.0 (36.1, 37.9)	31.3 (30.5, 32.1)
Select the full-sized	22.9 (22.1, 23.6)	22.8 (22.0, 23.5)	35.8 (34.9, 36.6)	36.1 (35.2, 36.9)	41.1 (40.2, 42.0)
Neither of these packages	9.9 (9.3, 10.4)	10.8 (10.3, 11.4)	10.4 (9.9, 11.0)	12.0 (11.4, 12.6)	12.2 (11.6, 12.8)
Number of observations	12,017	12,016	12,013	12,013	12,007

Notes: This table reports the response shares by options when respondents faced organic full-sized versus organic fresh-cut carrots. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the periods before COVID-19. Panel B is for the periods during COVID-19. The five columns are price pairs that respondents faced, and the unit is dollars per pound.

7.3. Econometric Strategy

I follow the approach of Hanemann (1984), who used a dichotomous choice survey to estimate WTP as a Hicksian welfare measure under the random utility framework. This approach is now standard in the WTP literature with binary choices. The strategy for organic is analogous to the econometric model for fresh cut, so I explain the specification only for the organic attribute.

Consider a population of respondents, denoted by I. Individual respondents face two carrot products, denoted by $j \in \{0,1\}$. Product 1 is organic, but product 0 is non-organic. Under the random utility framework, the indirect utility, U, for respondent $i \in I$ from product j is represented as

$$U_{i,j} = V\left(Org_j, Inc_i - P_j; X_i\right) + \epsilon_{i,j}. \tag{7.1}$$

The indirect utility is decomposed into a deterministic part, V, and a stochastic part, ϵ. The deterministic part is a function of organic indicator, Org_j, a product price, P_j, income, Inc_i, and some other variables that affect the utility, X_i. The binary variable, Org_j, is one for product 1 and zero for product 0. The vector, X_i, includes demographics and some other respondent-specific characteristics of surveys which will be explained below. The stochastic part is the utility determined by product attributes and respondent characteristics that respondent i perceives but researchers cannot observe.

Because of the utility maximization assumption, respondent i chooses product 1 rather than product 0 if the following condition holds:

$$V(Z_1, Inc_i - P_1; X_i) + \epsilon_{i,1} \geq V(Z_0, Inc_i - P_0; X_i) + \epsilon_{i,0}. \tag{7.2}$$

Because the error terms are random, the response is also random. The probability of choosing product 1, denoted by $Prob(Yes_i)$, is as follows:

$$Prob(Yes_i) = Prob(\eta_i \leq \Delta V_i), \tag{7.3}$$

where $\eta_i \equiv \epsilon_{i,0} - \epsilon_{i,1}$ and $\Delta V_i \equiv V(Org_1, Inc_i - P_1; X_i) - V(Org_0, Inc_i - P_0; X_i)$. Let $F_\eta(\cdot)$ denote the cumulative density function of η_i. Then, the probability of choosing product 1 can be written as

$$Prob(Yes_i) = F_\eta(\Delta V_i). \tag{7.4}$$

According to Hanemann (1984), the indirect utility is specified as linear in the price and the income: For all i, j,

$$V_{i,j} = \alpha_{i,j} + \beta\big(Inc_i - P_j\big). \tag{7.5}$$

For simplicity, the other variables except for income are suppressed (that is, the term $\alpha_{i,j}$ is a linear function of other variables). Then,

$$\Delta V_i = \Delta\alpha_i + \beta\big(P_{i,1} - P_{i,0}\big) = \Delta\alpha_i + \beta\Delta P_i, \tag{7.6}$$

where $\Delta\alpha_i \equiv \alpha_{1,i} - \alpha_{0,i}$.

Notice that respondent i chooses product 1 if ΔP_i is less than the WTP premium (WTP_i) for product 1 over product 0. Hence, $F_\eta(\Delta V_i)$ is identical as the probability when $\Delta P_i \leq WTP_i$. The term WTP_i is the WTP for organic because, for all $i \in I$, respondent i faces two products identical except for organic.

A distributional assumption on F_η is required for estimation. Consistent with prior work (for example, Hanemann 1984; Hanemann and Kanninen 1999), I assumed a logistic distribution on F_η. According to the properties of the logit specification, I obtain the following econometric specification:

$$\ln\left(\frac{Prob(Yes_i)}{1 - Prob(Yes_i)}\right) = \Delta V_i = \Delta\alpha_i + \beta\Delta P_i \tag{7.7}$$

The left-hand side is the log-odd ratio of the probability of choosing organic carrots over the probability of choosing non-organic carrots. The variable ΔP_i is the price difference between the two products given to respondent i.

The term $\Delta \alpha_i$ must be characterized to complete the model specification. The term is a function of respondent-specific characteristics in surveys, denoted by X_i, including demographics and survey environment features. Demographics include the female dummy, age group dummies (18 – 24, 25 – 34, 35 – 44, 45 – 54, 55 – 64, and 65+; the base is 18 – 24), and region dummies (Northeast, Midwest, South, and West; Northeast is the base). Respondent-specific features of surveys include the reference price, the reference product, the picture location of the reference product, the response time (unit: 100 seconds), and periods (December 2019 – January 2020, March – April 2020, June 2020, August 2020, October 2020, January 2021, and March 2021; the base is December 2019 – January 2020).

The reference price variable indicates the price of non-organic carrots when respondents faced non-organic versus organic carrots. The reference price variable is the price of full-sized carrots when respondents faced full-sized versus fresh-cut carrots. The value of this reference price is either \$1.00 or \$1.50 per pound. The reference price examines whether the probability of choosing organic (or fresh cut) depends on the absolute price, while the price difference variable examines the relative price impact.

The reference product is a dummy variable, and its value is zero if the pair (non-organic full-sized versus organic full-sized) was presented to respondents. Another group of respondents faced the pair: non-organic fresh-cut versus organic fresh-cut, and then the value of the reference product variable is one. Similarly, I specify the reference product variable in the regressions for fresh-cut. Specifically, the reference product variable is zero if respondents faced the pair: non-organic full-sized versus non-organic fresh cut. The reference product variable is one if they faced the pair (organic full-sized versus non-organic fresh cut). This reference product variable is to examine whether the choice probability of organic (or fresh cut) is determined by the existence of the fresh-cut attribute (or the organic attribute).

The pictures of the two products were presented side by side (Figure 7.1). The location of the organic picture was randomly set on the left or the right, with the same probability. The reference picture variable is a dummy variable, and its value is one if the organic picture is on the right-hand side, and zero if the organic picture is on the left-hand side. Similarly, the value of the variable is one if the fresh-cut picture is on the right-hand side and, otherwise, zero when respondents compared full-sized carrots and fresh-cut carrots. This variable controls the potential effect of the picture location on the responses.

I use the median of the WTP distribution to measure the central tendency of the welfare. The median is statistically preferred to a mean or some other measure because of less sensitivity to a small portion of respondents who value the targeted carrot attribute as very high or very low. The calculation of median WTP in a logit model was computed as the following formula (Hanemann, 1984):

$$median(WTP_i) = -\frac{\widehat{\Delta\alpha}}{\hat{\beta}}. \tag{7.8}$$

The numerator $\widehat{\Delta\alpha}$ represents the sum of the products of the means of the explanatory variables times their associated coefficient estimates. The denominator $\hat{\beta}$ is the coefficient estimate of the price difference. The 95% confidence intervals were computed by a bootstrapping technique with 1,000 random draws.

7.4. Estimation Results

7.4.1. Estimation Results of Utility Parameters in the Logit Regressions

In Table 7.9, columns labeled Model 1, Model 2, and Model 3 are for the respondents who faced non-organic and organic carrot pairs. These three models have five explanatory variables in common (the price difference, the reference price, the reference product, the picture location of the reference product, and the response time). The coefficient estimates of those five variables are similar across the three models. The coefficients of the price difference are all -2.1 and are all precisely estimated, which implies that the choice probability of organic falls as the price premium of organic over non-organic rises. The coefficients of the reference price are all around -0.20 and are also precisely estimated, which implies that the choice probability of organic falls as the price of non-organic rises, holding constant the price difference. The estimates of the coefficient of the dummy variable equal to one for the reference product, fresh cut, are estimated to be between 0.22 and 0.29. However, the standard errors are consistently slightly more than half the magnitude of the estimated coefficient. This means that the choice probability of organic is higher when respondents faced two fresh-cut carrot packages (non-organic fresh-cut versus organic fresh-cut ones) than when they faced two full-sized carrot packages (non-organic full-sized versus organic full-sized ones). This point will be discussed again in Models 4, 5, and 6.[1]

The coefficients for response time are also estimated to be positive. However, these coefficients for the effect of response time are also just below twice the magnitude of their

[1] As noted earlier, I consider four pairs of carrot packages: (1) (non-organic full-sized, organic full-sized), (2) non-organic fresh-cut, organic fresh-cut), (3) (non-organic full-sized, non-organic fresh-cut), (4) (organic full-sized, organic fresh-cut). The regressions about the organic attribute in Table 7.9 use all the responses from both (1) and (2). Also, the regressions about the fresh-cut attribute in Table 7.9 use all the responses from both (3) and (4). Here I implicitly assume that the estimation results would not change significantly regardless of dealing with (1) and (2) separately for estimating the organic WTP parameters and (3) and (4) separately for the fresh cut WTP parameters. For comparison, Appendix 7.A reports the results of regressions using (1) – (4) separately. Overall, the regression results are robust to the selection of subsamples.

standard errors, and thus I fail to reject a zero coefficient at the conventional 95% level of statistical significance. This point will be further discussed in Appendix 7.B.

Finally, note that respondents consistently were more likely to choose the package displayed on the right side, justifying our modeling procedure of rotating which package was displayed on that side. Also, the effect of position was twice as high (0.1 versus about 0.05) for the organic choice, which could indicate more attention when the choice was fresh cut (baby) versus full-sized carrots.

Model 1 includes respondents regardless of whether demographic information is available, and a dummy variable, denoted by "Demographics are inferred" in Table 7.9, is included in this model. The dummy variable is equal to one if demographics are inferred and, otherwise, zero. The coefficient of this dummy variable is estimated to be negative but is less than twice the magnitude of the standard error. Models 2 and 3 include variables representing three demographic categories (gender, age group, and regional group). The difference between the two models is that Model 3 uses population sampling weights based on demographics, while Model 2 does not. The estimation results are robust to the use of sampling weights.

Female respondents are more likely to choose organic than male respondents. Compared to 18 – 24 aged respondents, 25 – 44 aged respondents are more likely to choose organic. Compared to those in the Northeast, respondents in Midwest and South are less likely to choose organic, while those in the West are more likely to choose organic. There are many differences in food choices across regions. For example, the higher rate of preference for organic carrots could be related to the fact that more Asians live in the West. Using A.C. Nielsen Homescan panel data, Lucier and Lin (2007) found that Asian households bought more organic carrots in proportions than other race and ethnicity groups.

In Table 7.9, Models 4 to 6 provide results for the choice of fresh-cut carrots rather than the full-sized carrot alternative. Overall, the estimation results are similar among Models 4, 5, and 6. These three models correspond to Models 1 to 3 in the specifications of explanatory variables. The five variables (the price difference, the reference price, the reference product, the picture location of the reference product, and the response time) are used again in the regressions for fresh cut. The signs of those estimated coefficients and the degree of statistical significance are the same between the regressions for organic and fresh-cut choices. However, the magnitudes of the coefficients are different between the regressions for the two attributes. This point will be discussed more fully below in the context of the marginal effects of explanatory variables on the choice probability in percentage.

The estimated coefficient of the dummy variable for female respondents is slightly negative but small relative to its standard error in Models 5 and 6. The effect of age groups is also different in the regressions for fresh cut compared to organic. Compared to 18 – 24 aged respondents, older respondents are *less* likely to choose fresh cut relative to full-sized carrots. Furthermore, fresh-cut carrots are more likely to be chosen by respondents in the Midwest and South.

Table 7.10 reports the results when period dummies are included in the regression models. The period of December 2019 – January 2020 is the base and represents the period of time before the pandemic was widely publicized in each March 2020. A few of the period dummies are statistically significant at the 95% significance level, indicating differences in the intercept relative to the December 2019 – January 2000 data period but the magnitudes are small. The coefficient estimates for the other explanatory variables are robust to the inclusion of the period dummies when compared to the corresponding models (the organic model in Table 7.10

correspondents to Model 3 in Table 7.9; the fresh-cut model in Table 7.10 correspondents to Model 6 in Table 7.9).

Given the findings in Tables 7.9 and 7.10, my preferred specification of the model for the WTP estimation of carrot attributes is as follows. First, demographic variables (gender, age, and region) are included. Second, I use U.S. population sampling weights based on demographic groups to better represent the US population. Third, I do not exclude outliers in terms of the response time because the exclusion has no significant effect on the results of the other explanatory variables. Fourth, I include the period dummies to trace the pattern of response over time and across seasons. The WTP estimation results will be presented in the following subsection.

Using the regression model that I chose for the WTP estimation, the columns of Table 7.11 present the marginal effects of independent variables on the probability of choosing the organic product rather than the non-organic one. The marginal effects are evaluated at the mean values of individual independent variables. Similarly, the second column presents estimates for the fresh-cut choice.

To illustrate the interpretation of these estimates, consider the marginal effect of the price difference. If the price premium of organic over non-organic products is higher by $1.00 per pound, the probability of the respondent choosing an organic product is lower by about 50%. Similarly, if the price premium of fresh cut over full-sized products is higher by $1.00 per pound, the probability of the respondent choosing a fresh cut product is lower by about 28%. The choice probability mainly depends on the price difference variable, although other control variables, including demographics, are statistically significant.

Table 7.9. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Full Sample and Subsamples Including Only Respondents with Demographic Information

		Organic			Fresh cut		
Variable		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Price difference		-2.1 (0.020)	-2.1 (0.023)	-2.1 (0.024)	-1.2 (0.018)	-1.2 (0.020)	-1.2 (0.021)
Reference price		-0.20 (0.027)	-0.19 (0.030)	-0.22 (0.031)	-0.12 (0.027)	-0.14 (0.031)	-0.15 (0.032)
Reference product		0.022 (0.013)	0.0285 (0.0145)	0.026 (0.015)	0.054 (0.013)	0.053 (0.014)	0.058 (0.015)
Reference picture location: Right		0.10 (0.013)	0.11 (0.014)	0.11 (0.015)	0.061 (0.013)	0.045 (0.014)	0.044 (0.015)
Response time length (100 seconds)		0.0136 (0.00695)	0.014 (0.0080)	0.015 (0.0082)	-0.023 (0.0070)	-0.017 (0.0081)	-0.020 (0.0085)
Demographics are inferred		-0.025 (0.017)	-	-	0.069 (0.016)	-	-
Female		-	0.080 (0.015)	0.067 (0.015)	-	-0.016 (0.014)	-0.0054 (0.015)
Age	18 – 24	-	Base	Base	-	Base	Base
	25 – 34	-	0.12 (0.031)	0.098 (0.033)	-	-0.066 (0.030)	-0.059 (0.032)
	35 – 44	-	0.16 (0.031)	0.15 (0.033)	-	-0.081 (0.030)	-0.070 (0.032)
	45 – 54	-	0.054 (0.030)	0.018 (0.032)	-	-0.13 (0.030)	-0.12 (0.032)
	55 – 64	-	0.017 (0.030)	0.0039 (0.032)	-	-0.23 (0.029)	-0.21 (0.031)
	64+	-	-0.015 (0.031)	-0.036 (0.033)	-	-0.37 (0.030)	-0.36 (0.032)
Region	Northeast	-	Base	Base	-	Base	Base
	Midwest	-	-0.34 (0.024)	-0.34 (0.025)	-	0.23 (0.023)	0.23 (0.024)
	South	-	-0.15 (0.024)	-0.15 (0.024)	-	0.32 (0.023)	0.31 (0.024)
	West	-	0.12 (0.025)	0.11 (0.026)	-	-0.069 (0.024)	-0.080 (0.025)
Constant		0.62 (0.043)	0.60 (0.055)	0.67 (0.059)	0.62 (0.059)	0.75 (0.072)	0.73 (0.076)
Log pseudolikelihood		-65519	-52917	-52767	-68892	-54737	-54452
Chi squared		10438	8949	8081	4540	4331	3850
(P-value)		0.000	0.000	0.000	0.000	0.000	0.000
Number of observations		112,769	91,464	91,464	111,147	88,813	88,813

Notes. A logit regression is used (equation 7.7). The reference product is the full-sized product in organic regression whose sample comes from respondents comparing an organic carrot and a non-organic carrot. In the regression for fresh-cut, the non-organic product is the reference product. The variable, "demographics are inferred," is one for the respondents whose demographics are inferred, and, otherwise, zero. Models 1 to 3 are for organic, while Models 4 to 6 are for fresh-cut. Models 2, 3, 5 and 6 exclude respondents whose demographics are not inferred. Additionally, Models 3 and 6 use sampling weights based on demographic groups to make the sample represent the population.

Table 7.10. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Including Period Dummies

		Organic (weighted)	Fresh cut (weighted)
Variable		Coefficient	Coefficient
Price difference		-2.1 (0.024)	-1.2 (0.021)
Reference price		-0.22 (0.031)	-0.15 (0.032)
Reference product		0.026 (0.015)	0.060 (0.015)
Reference picture location: Right		0.11 (0.015)	0.044 (0.015)
Response time length (100 seconds)		0.016 (0.0083)	-0.021 (0.015)
Female		0.067 (0.015)	-0.0055 (0.015)
Age	18 – 24	Base	Base
	25 – 34	0.098 (0.033)	-0.059 (0.032)
	35 – 44	0.15 (0.033)	-0.071 (0.032)
	45 – 54	0.018 (0.032)	-0.12 (0.032)
	55 – 64	0.0039 (0.032)	-0.21 (0.031)
	64+	-0.036 (0.033)	-0.36 (0.032)
Region	Northeast	Base	Base
	Midwest	-0.34 (0.025)	0.23 (0.024)
	South	-0.15 (0.024)	0.31 (0.024)
	West	0.11 (0.026)	-0.081 (0.025)
Periods	December 2019 – January 2020	Base	Base
	March – April 2020	-0.015 (0.028)	-0.095 (0.027)
	June 2020	0.044 (0.028)	-0.073 (0.027)
	August 2020	0.034 (0.027)	-0.027 (0.026)
	October 2020	0.053 (0.027)	-0.090 (0.026)
	January 2021	0.043 (0.029)	-0.11 (0.028

March 2021	0.031	-0.081
	(0.029)	(0.028)
Constant	0.64	0.79
	(0.060)	(0.077)
Log pseudolikelihood	-52761	-54440
Chi squared	8109	3872
(P-value)	0.000	0.000
Number of observations	91,464	88,813

Notes. A logit regression is used (equation 7.7). The reference product is the full-sized product in organic regression whose sample comes from respondents comparing an organic carrot and a non-organic carrot. In the regression for fresh-cut, the non-organic product is the reference product. Sampling weights are used based on demographic groups to make the sample represent the population.

Table 7.11. Marginal Effects on Probability of Choosing Organic Carrots versus Non-Organic Carrots or Baby Carrots versus Full-Sized Carrots

		Organic	Fresh cut
Variable		Marginal effect	Marginal effect
Price difference		-0.50 (0.0057)	-0.28 (0.0052)
Reference price		-0.053 (0.0076)	-0.037 (0.0079)
Reference product		0.0062 (0.0037)	0.015 (0.0036)
Reference picture location: Right		0.026 (0.0037)	0.011 (0.0036)
Response time length (100 seconds)		0.0039 (0.0020)	-0.0051 (0.0021)
Female		0.16 (0.0037)	-0.0013 (0.0037)
Age	18 – 24	Base	Base
	25 – 34	0.024 (0.0080)	-0.014 (0.0077)
	35 – 44	0.036 (0.0079)	-0.017 (0.0076)
	45 – 54	0.0044 (0.0078)	-0.028 (0.0076)
	55 – 64	0.00095 (0.0078)	-0.052 (0.0075)
	64+	-0.0087 (0.0078)	-0.087 (0.0076)
Region	Northeast	Base	Base
	Midwest	-0.081 (0.0060)	0.056 (0.0059)
	South	-0.038 (0.0060)	0.075 (0.0058)
	West	0.028 (0.0065)	-0.020 (0.0063)
Periods	December 2019 – January 2020	Base	Base
	March – April 2020	-0.0037 (0.0067)	-0.023 (0.0065)
	June 2020	0.011 (0.0067)	-0.018 (0.0065)
	August 2020	0.0082 (0.0065)	-0.0065 (0.0063)
	October 2020	0.013 (0.0065)	-0.022 (0.0064)
	January 2021	0.011 (0.0069)	-0.026 (0.0068)
	March 2021	0.0076	-0.020

	(0.0071)	(0.0068)
Number of observations	91,464	88,813

Notes. The numbers are estimated based on the results of Table 7.10. The reference product is the full-sized product in organic regression whose sample comes from respondents comparing an organic carrot and a non-organic carrot. In the regression for fresh-cut, the non-organic product is the reference product. The standard errors are computed by the Delta method.

7.4.2. Estimates of WTPs for Carrot Attributes by Carrot Pairs

I use the logit regression results of Model 3 in Table 7.9 to obtain median WTP estimates for the organic attribute relative to non-organic carrots. I use regression results of Model 6 in Table 7.9 to obtain median WTP estimates of the fresh cut attribute relative to full-sized carrots. The formula for this calculation is presented above in equation (7.8).

Table 7.12 shows that the median WTP for organic full-sized is estimated to be about $0.206 per pound, relative to non-organic full-sized. The median WTP estimate rises slightly when organic fresh-cut is compared to non-organic fresh-cut. The changes in the median WTP estimates are not statistically significant according to 95% confidence intervals. On average, the median WTP for organic attribute relative to non-organic is estimated to be about $0.213 per pound.

The median WTP for non-organic fresh-cut is estimated to be about $0.479 per pound, relative to non-organic full-sized. The median WTP estimate also rises slightly when organic fresh-cut is compared to organic full-sized. The change in the two median WTP estimates is not statistically significant according to 95% confidence intervals. On average, the median WTP estimate for the fresh-cut attribute is $0.504 per pound.

Table 7.12. Median Willingness to Pay by Carrot Package Pairs

Unit: $ per pound	Median WTP	C.I.
Overall organic	0.213	(0.196, 0.229)
Non-organic full-sized vs. organic full-sized	0.206	(0.183, 0.230)
Non-organic fresh-cut vs. organic fresh-cut	0.219	(0.208, 0.230)
Overall fresh-cut	0.504	(0.431, 0.578)
Non-organic fresh-cut vs. non-organic full-sized	0.479	(0.394, 0.565)
Organic fresh-cut vs. organic full-sized	0.529	(0.468, 0.591)

Notes. I use the results of Model 3 in Table 7.9 to obtain median WTP estimates for the organic attribute. I also use the results of Model 6 in Table 7.9 to obtain median WTP estimates for the fresh-cut attribute. The median WTP formula is equation (7.8). The margins of error are constructed based on a bootstrapping technique, with 1,000 draws.

7.4.3. Estimates of WTPs for Carrot Attributes by Demographic Attributes of Respondents

I use again Model 3 in Table 7.9 to explore variations of the median WTP estimates of the organic attribute by demographic attributes of respondents (gender, age, and region). Similarly, I use again Model 6 in Table 7.9 to explore the median WTP estimates variations of the fresh-cut attribute by demographic attributes.

In Table 7.13, the median WTP estimates of the organic attribute are higher on average among respondents who are female, aged in the range from 25 to 34 or 35 to 44, and from coastal regions (Northeast and West). The changes in the median WTP estimates are not statistically significant between female and male respondents according to 95% confidence intervals. However, the estimated changes are statistically significant among different age groups and different regions according to 95% confidence intervals.

The variation patterns of the median WTP estimates are different between the organic attribute and the fresh-cut attribute. The median WTP estimates of the fresh-cut attribute are higher among respondents who are male, aged in the range of 18 – 24, 25 – 34, and 35 – 44, and from the Midwest and South regions.

Table 7.13. Median Willingness to Pay by Demographic Attributes of Respondents

	Organic attribute		Fresh-cut attribute	
	Median WTP	C.I.	Median WTP	C.I.
	$ per pound			
Overall	$0.213	($0.196, $0.229)	$0.504	($0.431, $0.578)
Female	$0.219	($0.202, $0.227)	$0.503	($0.429, $0.577)
Male	$0.187	($0.169, $0.205)	$0.508	($0.433, $0.583)
18 – 24	$0.193	($0.163, $0.223)	$0.636	($0.552, $0.720)
25 – 34	$0.240	($0.217, $0.264)	$0.585	($0.505, $0.665)
35 – 44	$0.265	($0.241, $0.289)	$0.575	($0.497, $0.654)
45 – 54	$0.202	($0.180, $0.224)	$0.535	($0.458, $0.613)
55 – 64	$0.195	($0.173, $0.217)	$0.453	($0.377, $0.529)
64 +	$0.176	($0.153, $0.198)	$0.329	($0.250, $0.408)
Northeast	$0.275	($0.250, $0.300)	$0.372	($0.291, $0.453)
Midwest	$0.111	($0.0904, $0.131)	$0.567	($0.491, $0.643)
South	$0.200	($0.181, $0.220)	$0.636	($0.560, $0.712)
West	$0.330	($0.309, $0.351)	$0.303	($0.226, $0.380)

Note. I use the results of Model 3 in Table 7.9 to obtain median WTP estimates for the organic attribute. I also use the results of Model 6 in Table 7.9 to obtain median WTP estimates for the fresh-cut attribute. The median WTP formula is equation (7.8). The margins of error are constructed based on a bootstrapping technique, with 1,000 draws.

7.4.4. Estimates of WTPs for Carrot Attributes by Period

The median WTP estimate for the organic attribute is estimated to be about $0.20 per pound for respondents in the December 2019 – January 2020 period, which was before the COVID-19 pandemic had garnered public and policy attention in the United States. The median WTP for the fresh-cut attribute is estimated to be about $0.50 per pound for respondents in the December 2019 to January 2020 period (Table 7.14).

The median WTP estimates of organic range from $0.19 to $0.23 per pound between March 2020 to October 2020. Thus, despite unprecedented economic shocks, social dislocation, and supply chain disruptions, the estimates over this period range between one cent (5%) lower and three cents (15%) higher compared to the December 2019- January 2020 period. Moreover, the 95% confidence intervals overlap across these periods. The median WTP estimates for the organic attribute is slightly smaller and closer to the initial period for the January and March 2021 rounds of the survey.

The median WTP for the fresh-cut attribute was $0.56 for the December 2019 – January 2020 round of the survey. In subsequent rounds, the median WTP estimates range from $0.47 to $0.54 per pound, slightly less than the median WTP estimate ($0.56 per pound) before COVID-19. However, according to 95% confidence intervals, the changes in the median WTP estimates are not statistically significant for both attributes over the periods during the pandemic. Overall, the median WTP estimates are robust before and during the pandemic.

Table 7.14. Median WTP estimates for Carrot Attributes by Periods

Period	Organic		Fresh cut	
	Median WTP	C.I.	Median WTP	C.I.
Dec 2019 – Jan 2020	$0.20	($0.18, $0.22)	$0.56	($0.48, $0.63)
March 2020	$0.19	($0.17, $0.22)	$0.48	($0.40, $0.56)
June 2020	$0.22	($0.20, $0.25)	$0.49	($0.41, $0.57)
August 2020	$0.22	($0.19, $0.24)	$0.54	($0.46, $0.61)
October 2020	$0.23	($0.20, $0.25)	$0.48	($0.40, $0.56)
January 2021	$0.22	($0.19, $0.25)	$0.47	($0.38, $0.55)
March 2021	$0.21	($0.19, $0.24)	$0.49	($0.40, $0.57)
Note. The logit regression results in Table 7.10 are used to obtain median WTP estimates. The formula is equation (7.8). The margins of error are constructed based on a bootstrapping technique, with 1,000 draws.				

7.4.5. Projected Shares of Organic Carrots and Fresh-Cut Carrots by Price Premium

I use the estimation results in Table 7.9 to project the shares of organic carrots and fresh-cut carrots, given the observed average retail price premium in the U.S. market in 2019. For average prices (which I understand vary by region and date), I use the prices reported in Table 5.2, Chapter 5. These prices report the average retail prices (and calculated price premiums) by whether carrots are organic or non-organic and fresh-cut or full-sized. These data are reported by the Agricultural Marketing Service, U.S. Department of Agriculture (USDA-AMS 2020).

The projected shares are calculated using the following formula:

$$Prob = \frac{\exp\left(\widehat{\Delta\alpha} + \hat{\beta}\Delta P^*\right)}{1 + \exp\left(\widehat{\Delta\alpha} + \hat{\beta}\Delta P^*\right)}. \tag{7.9}$$

The term ΔP^* is the average retail price premium in the data. This value is the premium of organic over non-organic or the premium of fresh cut over full-sized depending on the case considered. The term $\hat{\beta}$ is the coefficient estimate of the price difference in Table 7.9, and the value depends on either the regressions for organic (from Model 3) or for fresh cut (from Model 6). The term $\widehat{\Delta\alpha}$ is the sum of the products of the means of the explanatory variables times their associated coefficient estimates in Table 7.9.

Table 7.15 shows the projected shares given the observed average retail price premium in the U.S. retail market. First, for organic and non-organic full-sized carrot products, the projected share of organic is 32% when the price premium of organic full-sized is \$0.58 per pound over non-organic full-sized carrots. Second, for organic and non-organic fresh-cut carrot products, the projected share of organic is about 33% when the price premium of organic fresh-cut is \$0.57 per pound over non-organic fresh-cut carrot package. Third, for non-organic full-sized and fresh-cut carrot products, the projected share of fresh cut is about 51% when the price premium of non-organic fresh-cut is \$0.44 per pound over non-organic full-sized package. Fourth, for organic full-sized and fresh-cut carrot products, the projected share of fresh cut is about 53% when the price premium of organic fresh-cut is \$0.41 per pound over organic full-sized package.

The retail price premiums of organic packages over non-organic ones (or fresh-cut packages over full-sized ones) differ across time periods and regions. To illustrate how the projected shares change by different price premiums, I use three price premiums, \$0.00, \$0.50, and \$1.00 per pound (Table 7.16). The projected shares decrease as the price premiums increase. When I calculate shares for organic and non-organic full-sized carrot products, the projected organic shares are about 60% for a premium of $0.00, about 36% for a $0.50 per pound premium, and about 16% for a $1.00 per pound price premium. The organic shares for alternative price differences for fresh-cut carrots are very similar to the shares for full-sized carrots.

When I calculate shares for fresh cut versus full-sized non-organic carrot products, the projected fresh cut shares are to be about 65% for a premium of $0.00, about 50% for a $0.50 per pound premium, and about 36% for a $1.00 per pound price premium. The fresh cut shares for alternative price differences for organic carrots are similar to the shares for conventional carrots.

The projected shares are not directly comparable to U.S. retail carrot market shares. In the retail market, products usually differ in attributes in addition to just fresh cut versus full sized and organic versus conventional, including brand, package labeling, quantity in the package, location on the shelf, and more. If organic carrots are more likely to have specific product attributes for which consumers are willing to pay extra than non-organic carrots, the observed organic shares would be higher than the projected shares. Nonetheless, it is helpful to note that these shares for organic and fresh cuts are in the range generally found in the U.S. market.

For comparison to the projected shares, let us see some facts on the quantity shares by organic and fresh cut. Organic carrots account for a small share of domestic production (14% in 2019, USDA-NASS 2019). “Organic” carrots used in this calculation only include those labeled as USDA certified. To my knowledge, there is no direct information about the retail share of organic carrots in the United States. However, this small share in the domestic production indicates that organic carrots’ quantity share at retail would be small, which is consistent with the findings. Also, to my knowledge, there is no publicly available information about the retail share of fresh-cut carrots. But fresh-cut carrots account for about 54% of retail, according to Winsight

Grocery Business (2019), which is a company that provides information about U.S. food retail industries.[2] The majority of fresh-cut carrots at retail reported by industry information is consistent with the findings in my research.

Table 7.15. Projected Shares of Organic Carrots and Fresh-Cut Carrots Given the Observed Average Retail Price Premium

	Average retail price premium	Projected share	Confidence interval
	$ per pound	%	%
Organic full-sized vs. non-organic full-sized	$0.58	31.6	(30.6, 32.6)
Organic fresh cut vs. non-organic fresh cut	$0.57	32.6	(32.1, 33.2)
Non-organic fresh cut vs. non-organic full-sized	$0.44	51.1	(50.1, 52.2)
Organic fresh cut vs. organic full-sized	$0.41	53.5	(53.0, 54.0)
Note. The average retail price premiums are the same values in Table 5.2 in Chapter 5. The original data source is Agricultural Marketing Service, U.S. Department of Agriculture (USDA-AMS 2020). The coefficient estimates in Table 7.9 (Models 3 and 6) are used to project the shares. The confidence intervals are constructed based on a bootstrapping technique, with 1,000 draws.			

Table 7.16. Projected Shares of Organic Carrots and Fresh-Cut Carrots by Price Premium

Panel A. Organic versus non-organic				
Price premium	Organic full-sized versus non-organic full-sized		Organic fresh cut versus non-organic fresh cut	
	Projected share	C.I.	Projected share	C.I.
$0.00	60.5	(59.3, 61.6)	61.1	(60.5, 61.7)
$0.50	35.3	(34.2, 36.3)	35.9	(35.4, 36.4)
$1.00	16.3	(15.5, 17.0)	16.6	(16.1, 17.2)
Panel B. Fresh cut versus full-sized				
Price premium	Non-organic fresh cut versus non-organic full-sized		Organic fresh cut versus organic full-sized	
$0.00	63.6	(62.5, 64.8)	65.0	(64.3, 65.6)
$0.50	49.4	(48.4, 50.4)	50.9	(50.3, 51.4)
$1.00	35.3	(34.5, 36.0)	36.6	(36.1, 37.1)
Notes. The coefficient estimates in Table 7.9 (Models 3 and 6) are used to project the shares. The confidence intervals are constructed based on a bootstrapping technique, with 1,000 draws.				

[2] The carrot shares information originally came from IRI retail data, and the value (54%) would represent the U.S. carrot retail market under the assumption that the IRI retail data represent it.

7.5. Summary of Findings in Chapters 5 to 7 and Implications

This section summarizes the findings on demand for food attributes linked to production practices. I also highlight implications for policy discussions and future research direction.

7.5.1. Summary of Findings

Let me first summarize findings about the willingness to pay for the organic attribute in carrots. First, data show consistently positive estimates of the median WTP for the organic attribute across different model specifications. Second, the magnitude of the median WTP estimate differ between the situation where respondents were shown a single product and asked about maximum WTP ($0.10 per pound), versus when respondents were asked to choose between two products, where one had the one organic attribute ($0.20 per pound.). Third, the regression results for WTP for the organic attribute are robust across a variety of model specifications: (i) the full sample versus a subsample with only respondents whose demographics are available, (ii) the full sample versus subsamples without outliers in terms of the response time, and (iii) the regressions with and without sampling weights based on demographic groups.

A second group of WTP findings is about the willingness to pay for the fresh-cut attribute (also often called "baby" carrots. First, when respondents face a single product picture and Multiple-Choice questions about WTP, data indicate a negative median WTP estimate. Second, using the single product picture Multiple-Choice questions, the median WTP estimate value is robust on which WTP intervals are used. Third, when respondents face side-by-side pictures of packages of conventional and fresh cut carrots they have a strong significant positive WTP for the fresh-cut carrot package. Finally, all estimates of parameters are robust across over a variety of model specifications: (i) the full sample versus a subsample with only respondents whose demographics are available, (ii) the full sample versus subsamples without outliers in terms of the response time, and (iii) the regressions with and without sampling weights based on demographic groups.

The third group of findings is about whether the WTP estimation results are robust over time periods when the survey was circulated across about 15 months from December 2019 through Mach 2021, which is before and during the COVID-19 pandemic. The estimation results are not significantly different across time periods. There is no evidence of seasonality in WTP and no evidence that the pandemic affected WTP for carrots or for the WTP for the organic or fresh cut attribute.

7.5.2. Implications for Further Economic Research

My research supports evidence of a positive median WTP for organic food. Carrots are a popular vegetable, so I believe this research can help economists obtain a comprehensive understanding of organic food demand.

I found that for the fresh cut attribute when respondents did not face the two packages side by side and expressed the willingness to pay for a single package, they stated lower WTP for one-pound fresh cut carrot packages relative to full-sized carrots. This result is inconsistent with the popularity of fresh-cut carrots even with a significant retail price premium (about $0.50 per pound according to USDA-AMS (2020). Hence, I believe there is a need to explore the demand for fresh cut using different data sources, econometric strategies, and vegetables and fruits. The WTP for fresh cut is consistently positive when the consumers see the conventional and fresh cut package side-by-side. Therefore, more research is needed to understand how to elicit WTP in these circumstances.

Another important finding is consistency of the WTP for food product attributes over time periods. Although the robustness of the WTP and other demand parameters is crucial for using the parameter estimates obtained from prior work, the robustness has received little attention in agricultural and food economics literature. I explore the robustness using surveys conducted multiple times with identical questionnaires and administration. My example would be valuable for this exploration because COVID-19 seems a significant exogenous shock on food industries in general.

I expect economists to be interested in the effectiveness of the simple survey design and cost-effective method of data collection used in this research. Using a single question that took less than one minute of the respondents' time, we were able to collect responses from a large representative sample of individuals who claim to be buyers of carrots. These respondents provided answers that were broadly consistent with expectations about carrot demand and yielded insights as well.

The large number of respondents who were surveyed at a cost of about $0.10 per usable response, provided a high estimation precision. At the same time, we avoided the potential bias from surveys in which each respondent answers multiple questions, where prior questions possibly affect the responses to the following questions. We also avoided interactions with survey administrators that may affect responses. Such effects may be of concern, especially when asking about attributes such as organic production, animal welfare or other product attributes which related to social or ideological preferences or expectations.

This study finds that WTP estimates are sensitive to the form of display that respondents face. The responses seem more reliable and robust when the respondents faced pictures of the products to be compared. We plan more exploration of survey design in this context to better replicated the retail choice experience. More research to compare survey responses with detailed observational purchase data, especially retail scanner data would be useful. Scanner data provides detailed information about detailed product attributes and package features that could be compared to survey responses to questions about these product attributes.

Appendix 7.A. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples by Four Different Pairs of Carrot Packages

I consider four pairs of carrot packages: (1) (non-organic full-sized, organic full-sized), (2) non-organic fresh-cut, organic fresh-cut), (3) (non-organic full-sized, non-organic fresh-cut), (4) (organic full-sized, organic fresh-cut).

The regressions about the organic attribute in Table 7.9 use all the responses from both (1) and (2). Also, the regressions about the fresh-cut attribute in Table 7.9 use all the responses from both (3) and (4). In the regressions of Table 7.9, I implicitly assume that the estimation results would not change significantly regardless of dealing with (1) and (2) separately for estimating the organic WTP parameters and (3) and (4) separately for the fresh cut WTP parameters.

For comparison, this appendix reports the results of regressions using (1) – (4) separately. I focus on the regression specification that I finally selected to estimate WTP parameters, which uses responses from respondents with demographic information and applies sampling weights by U.S. population demographic groups characterized by gender, age, and region (corresponds to Model 3 of Table 7.9 for organic and Model 6 of Table 7.9 for fresh cut). Overall, the regression results are robust to the selection of subsamples.

Table 7.A.1. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples by Four Different Pairs of Carrot Packages

Variable		Organic: Non-organic full-sized vs. organic full-sized	Organic: Non-organic fresh-cut vs. organic fresh-cut	Organic: All	Fresh cut: Non-organic full-sized vs. non-organic fresh-cut	Fresh cut: Organic full-sized vs. organic fresh-cut	Fresh cut: All
Price difference		-2.1 (0.034)	-2.1 (0.034)	-2.1 (0.024)	-1.1 (0.030)	-1.2 (0.031)	-1.2 (0.021)
Reference price		-0.19 (0.044)	-0.24 (0.045)	-0.22 (0.031)	-0.079 (0.045)	-0.23 (0.047)	-0.15 (0.032)
Reference picture location: Right		0.13 (0.021)	0.083 (0.022)	0.11 (0.015)	0.050 (0.021)	0.037 (0.022)	0.044 (0.015)
Response time length (100 seconds)		0.018 (0.0123)	0.013 (0.011)	0.015 (0.0082)	-0.0097 (0.011)	-0.031 (0.013)	-0.020 (0.0085)
Female		0.091 (0.0216)	0.045 (0.022)	0.067 (0.015)	-0.018 (0.021)	0.0075 (0.022)	-0.0054 (0.015)
Age	18 – 24	Base	Base	Base	Base	Base	Base
	25 – 34	0.036 (0.046)	0.16 (0.047)	0.098 (0.033)	-0.054 (0.045)	-0.066 (0.046)	-0.059 (0.032)
	35 – 44	0.11 (0.0455)	0.18 (0.047)	0.15 (0.033)	-0.073 (0.044)	-0.071 (0.046)	-0.070 (0.032)
	45 – 54	-0.027 (0.0451)	0.062 (0.046)	0.018 (0.032)	-0.095 (0.044)	-0.14 (0.045)	-0.12 (0.032)
	55 – 64	-0.071 (0.0446)	0.075 (0.046)	0.0039 (0.032)	-0.20 (0.044)	-0.23 (0.045)	-0.21 (0.031)
	64+	-0.061 (0.0451)	-0.012 (0.047)	-0.036 (0.033)	-0.33 (0.044)	-0.39 (0.046)	-0.36 (0.032)
Region	Northeast	Base	Base	Base	Base	Base	Base
	Midwest	-0.35 (0.0346)	-0.33 (0.036)	-0.34 (0.025)	0.26 (0.033)	0.20 (0.035)	0.23 (0.024)
	South	-0.18 (0.0340)	-0.13 (0.035)	-0.15 (0.024)	0.35 (0.033)	0.26 (0.034)	0.31 (0.024)
	West	0.079 (0.0363)	0.15 (0.037)	0.11 (0.026)	-0.093 (0.035)	-0.068 (0.036)	-0.080 (0.025)
Constant		0.70 (0.0757)	0.71 (0.078)	0.67 (0.059)	0.76 (0.076)	1.11 (0.079)	0.73 (0.076)
Log pseudolikelihood		-25825	-26932	-52767	-27464	-26974	-54452
Chi squared		4054	4041	8081	1882	1970	3850
(P-value)		0.000	0.000	0.000	0.000	0.000	0.000
Number of observations		47,596	43,868	91,464	47,305	41,508	88,813

Notes. A logit regression is used (equation 7.7). The column, "All," of the organic regressions use samples from both (1) (non-organic full-sized, organic full-sized) and (2) non-organic fresh-cut, organic fresh-cut), which corresponds to Model 3 of Table 7.9. Similarly, the column, "All," of the fresh-cut regressions use samples from both (3) (non-organic full-sized, non-organic fresh-cut) and (4) (organic full-sized, organic fresh-cut), which corresponds to Model 6 of Table 7.9. Sampling weights are used based on demographic groups to make the sample represent the population.

Appendix 7.B. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Subsamples with Outliers in the Response Time

Tables 7.B.1 and 7.B.2 include only respondents whose response time ranges are with in the central part of the response time distribution. As before, I leave out the lower 5% (below about 6.7 seconds) and the upper 5% (above about 55 seconds). Table 7.B.1 is comparable to Table 7.1, and Table 7.B.2 is comparable to Table 7.2. Overall, the results are robust with and without outliers in response time.

Table 7.B.3 examines the effect of outliers on the regression results. This table reports results from the same models as Table 7.9. The one difference between the two tables is that the estimates reported in Table 7.B.3 exclude respondents whose response time is out of the range from 5% to 95% of the population of respondents. After excluding outliers, the coefficient of the response time variable is now precisely estimated to be positive for organic but negative for fresh-cut. Importantly, the coefficient estimates of the other variables are very similar across the models, except for the response time variable itself. Thus, these results are robust to response time.

Table 7.B.1. Summary Statistics, Responses from Yes-No Questions, Non-Organic versus Organic, A Subsample of Respondents in the Range from 5% to 95% in Response Time

Price for organic	$1.00	$1.50	$1.50	$2.00	$2.00
Price for non-organic	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus organic full-sized					
I don't buy carrots	13.8 (13.2, 14.5)	14.6 (14.0, 15.2)	13.2 (12.7, 13.8)	12.9 (12.4, 13.5)	13.2 (12.7, 13.8)
Select the organic	48.6 (47.8, 49.5)	48.6 (47.8, 49.5)	22.6 (21.9, 23.3)	22.9 (22.2, 23.6)	18.1 (17.5, 18.8)
Select the non-organic	28.5 (27.7, 29.3)	27.0 (26.3, 27.8)	57.3 (56.4, 58.0)	56.6 (55.8, 57.4)	61.7 (60.9, 62.5)
Neither of these packages	9.0 (8.5, 9.5)	9.7 (9.2, 10.3)	6.9 (6.5, 7.3)	7.6 (7.2, 8.1)	7.0 (6.6, 7.4)
Number of observations	12,688	12,613	14,466	14,456	14,422
Panel B. Non-organic fresh-cut versus organic fresh cut					
I don't buy carrots	14.0 (13.4, 14.6)	13.9 (13.3, 14.5)	12.4 (11.8, 13.0)	12.8 (12.2, 13.4)	13.1 (12.5, 13.7)
Select the organic	49.1 (48.3, 50.0)	50.3 (49.4, 51.2)	23.8 (23.0, 24.5)	23.3 (22.5, 24.0)	18.0 (17.4, 18.7)
Select the non-organic	28.3 (27.5, 29.0)	27.1 (26.3, 27.8)	56.4 (55.6, 57.3)	56.2 (55.3, 57.0)	61.1 (60.3, 62.0)
Neither of these packages	8.6 (8.1, 9.1)	8.8 (8.3, 9.3)	7.4 (7.0, 7.9)	7.8 (7.3, 8.2)	7.8 (7.3, 8.3)
Number of observations	12,713	12,684	12,660	12,658	12,723

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for organic. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus organic full-sized carrots. Panel B is for the case when they faced non-organic fresh-cut versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.B.2. Summary Statistics, Responses from Yes-No Questions, Full-Sized versus Fresh-Cut, A Subsample of Respondents in the Range from 5% to 95% in Response Time

Price for fresh cut	$1.00	$1.50	$1.50	$2.00	$2.00
Price for full-sized	$1.00	$1.50	$1.00	$1.50	$1.00
	%	%	%	%	%
Panel A. Non-organic full-sized versus non-organic fresh cut					
I don't buy carrots	12.7 (12.2, 13.3)	12.8 (12.3, 13.4)	13.8 (13.2, 14.4)	13.7 (13.2, 14.3)	14.1 (13.5, 14.7)
Select the fresh cut	54.6 (53.7, 55.5)	55.0 (54.1, 55.8)	38.5 (37.7, 39.3)	40.6 (39.8, 41.4)	33.4 (32.7, 34.2)
Select the full-sized	25.7 (25.0, 26.5)	24.8 (24.0, 25.5)	38.5 (37.7, 39.3)	38.0 (37.2, 38.8)	44.8 (44.0, 45.6)
Neither of these packages	7.0 (6.5, 7.4)	7.4 (7.0, 7.9)	7.2 (6.8, 7.6)	7.7 (7.3, 8.1)	7.7 (7.3, 8.2)
Number of observations	12,623	12,605	14,377	14,351	14,354
Panel B. Organic full-sized versus organic fresh cut					
I don't buy carrots	12.8 (12.2, 13.4)	13.7 (13.1, 14.3)	14.0 (13.5, 14.7)	14.2 (13.6, 14.8)	15.4 (14.7, 16.1)
Select the fresh cut	55.3 (54.4, 56.1)	53.9 (53.0, 54.8)	40.2 (39.4, 41.1)	38.2 (37.3, 39.0)	32.1 (31.3, 32.9)
Select the full-sized	22.6 (21.9, 23.4)	22.1 (21.4, 22.8)	36.0 (35.2, 36.9)	36.0 (35.1, 36.8)	41.0 (40.2, 41.9)
Neither of these packages	9.3 (8.8, 9.8)	10.4 (9.8, 10.9)	9.7 (9.2, 10.2)	11.6 (11.1, 12.2)	11.5 (11.0, 12.1)
Number of observations	12,596	12,563	12,542	12,567	12,540

Notes: This table reports the response shares by options when respondents faced two identical carrot products except for fresh cut. The numbers in parentheses are confidence intervals under a 95% significance level. Panel A is for the case when respondents faced non-organic full-sized versus non-organic fresh-cut carrots. Panel B is for the case when they faced organic full-sized versus organic fresh-cut carrots. The five columns are price pairs that respondents faced, and the unit is dollars per pound. Three price pairs, ($1.50, $1.00), ($2.00, $1.50), and ($2.00, $1.00), have about 2,000 more observations than the others because those cases were collected additionally in December 2019.

Table 7.B.3. Effects of Price Difference and Other Variables on Choice of Organic and Fresh Cut Carrots: Full Sample and Different Subsamples with Outliers in the Response Time

		Organic			Fresh cut		
Variable		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Price difference		-2.1 (0.024)	-2.1 (0.024)	-2.1 (0.025)	-1.2 (0.021)	-1.2 (0.022)	-1.2 (0.023)
Reference price		-0.22 (0.031)	-0.22 (0.032)	-0.24 (0.033)	-0.15 (0.032)	-0.15 (0.033)	-0.14 (0.034)
Reference product		0.026 (0.015)	0.028 (0.015)	0.033 (0.016)	0.058 (0.015)	0.067 (0.015)	0.082 (0.016)
Reference picture location: Right		0.11 (0.015)	0.11 (0.015)	0.086 (0.016)	0.044 (0.015)	0.047 (0.015)	0.023 (0.016)
Response time length (100 seconds)		0.015 (0.0082)	0.28 (0.049)	0.63 (0.089)	-0.020 (0.0085)	-0.51 (0.047)	-1.16 (0.084)
Female		0.067 (0.015)	0.073 (0.016)	0.092 (0.016)	-0.0054 (0.015)	-0.014 (0.015)	-0.0313 (0.0159)
Age	18 – 24	Base	Base	Base	Base	Base	Base
	25 – 34	0.098 (0.033)	0.10 (0.034)	0.11 (0.035)	-0.059 (0.032)	-0.067 (0.033)	-0.079 (0.034)
	35 – 44	0.15 (0.033)	0.15 (0.033)	0.14 (0.035)	-0.070 (0.032)	-0.075 (0.032)	-0.073 (0.034)
	45 – 54	0.018 (0.032)	0.015 (0.033)	0.0065 (0.034)	-0.12 (0.032)	-0.11 (0.032)	-0.097 (0.034)
	55 – 64	0.0039 (0.032)	-0.0091 (0.032)	-0.012 (0.034)	-0.21 (0.031)	-0.20 (0.032)	-0.17 (0.033)
	64+	-0.036 (0.033)	-0.052 (0.033)	-0.068 (0.035)	-0.36 (0.032)	-0.32 (0.032)	-0.30 (0.034)
Region	Northeast	Base	Base	Base	Base	Base	Base
	Midwest	-0.34 (0.025)	-0.33 (0.025)	-0.35 (0.026)	0.23 (0.024)	0.22 (0.024)	0.22 (0.025)
	South	-0.15 (0.024)	-0.16 (0.025)	-0.17 (0.026)	0.31 (0.024)	0.31 (0.024)	0.33 (0.025)
	West	0.11 (0.026)	0.11 (0.026)	0.10 (0.028)	-0.080 (0.025)	-0.087 (0.026)	-0.088 (0.027)
Constant		0.67 (0.059)	0.61 (0.060)	0.59 (0.065)	0.73 (0.076)	0.81 (0.078)	0.90 (0.082)
Log pseudolikelihood		-52767	-51662	-47356	-54452	-53181	-48627
Chi squared		8081	8016	7632	3850	3975	3825
(P-value)		0.000	0.000	0.000	0.000	0.000	0.000
Number of observations		91,464	89,811	82,853	88,813	87,056	80,011

Notes. A logit regression is used (equation 7.7). The reference product is the full-sized product in organic regression whose sample comes from respondents comparing an organic carrot and a non-organic carrot. In the regression for fresh-cut, the non-organic product is the reference product. The variable, “demographics are inferred,” is one for the respondents whose demographics are inferred, and, otherwise, zero. Models 1 to 3 are for organic, while Models 4 to 6 are for fresh-cut. Models 2, 3, 5 and 6 exclude respondents whose demographics are not inferred. Additionally, Models 3 and 6 use sampling weights based on demographic groups to make the sample represent the population. Compared to Table 7.9, this table excludes respondents whose response time is out of the range from 5% to 95%.

References

Gschwandtner, A., and M. Burton. 2020. “Comparing Treatments to Reduce Hypothetical Bias in Choice Experiments Regarding Organic Food.” *European Review of Agricultural Economics* 47(3): 1302-1337.

Hanemann, W. M. 1984. “Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses.” *American Journal of Agricultural Economics* 66(3): 332-341.

Hanemann, W. M., and B. Kanninen. 1999. “The Statistical Analysis of Discrete-Response.” In I. Bateman, K. Willis, ed. *Valuing the Environment Preferences: Theory and Practice of the Contingent Valuation Method in the US, EC and Developing Countries.* Oxford University Press, pp.302-441.

Lucier, G., and B. H. Lin. 2007. *Factors Affecting Carrot Consumption in the United States*. Outlook Report. Economic Research Service, U.S. Department of Agriculture. No. VGS-31901: 1-21.

U.S. Department of Agriculture, Agricultural Marketing Service. 2020. *Retail Reports*. Custom Reports (Data Queries), Specialty Crops. Available at: https://www.ams.usda.gov/market-news/retail.

U.S. Department of Agriculture, Economic Research Service. 2020. *Vegetables and Pulses Yearbook Tables*. Available at: https://www.ers.usda.gov/data-products/vegetables-and-pulses-data/vegetables-and-pulses-yearbook-tables/. (Last accessed February 8, 2021).

U.S. Department of Agriculture, National Agricultural Statistics Service. 2019. (USDA-NASS 2019). *Table 3. Fresh and Processed Certified Organic Vegetables Grown in the Open Value of Sales: 2019*. 2019 Organic Survey, Census of Agriculture. Available at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Organics/organics_1_003%20_003.pdf. Accessed August 15, 2022.

Winsight Grocery Business. 2019. 2019 *Fresh Food Handbook*. Available at: https://digitalmag.grocerybusiness.com/winsightgrocerybusiness/fresh_food_handbook_2019?pg=1#pg1. (Last accessed February 8, 2021).

Chapter 8. Conclusions

This dissertation is comprised of two main parts that each deal with the economics of food attributes linked to production practices. The first main topic is the economic implications of regulations of sow housing practices related to pork products sold within California. The second main topic is the econometric estimation of demand parameters for carrot product attributes: defined by organic farm production and fresh-cut processing practices.

Governments impose regulations on products sold within their jurisdiction that limit farm practices that occur outside their jurisdiction. Chapter 2 provides empirical context and background for such regulations, including examples that document the spread of this type of regulation. Chapter 3 describes and models the supply chain impacts of regulations that followed from California's Proposition 12 limited the sale of certain pork products in California based on compliance with specific farm practices for sow treatment and housing practices. Compliance costs would differ across farms because about 30% of North American sows are already housed in groups, and those farms will have lower costs of conversion to Prop 12 standards relative to typical operations that use stall housing for sows. Inframarginal converters whose compliance costs are very low will earn incremental profits from converting. Another important implication of my economic model is that others in the supply chain from farms to the California pork market, including primary processors, wholesalers, retailers, and foodservice providers, also have incremental costs to comply with Prop 12.

Prop 12 covers only about 60 to 65 percent of pork products from a hog. The non-covered pork products produced from the Prop 12-compliant hog used for covered pork. Given competition among producers and arbitrage in pork markets the cost of compliance may only be recouped from higher prices for covered pork product sold in California. These higher prices of covered products imply that processors have an incentive to increase, where possible, the proportion of covered pork.

The calibrated simulations model results in Chapter 4 indicate that compliant farrowing operations incur higher costs (by about 4%), and compliant processing and distribution operations incur higher costs (by about 5%). With higher prices of uncooked pork cuts (by about 7%), California consumers of uncooked pork cuts have substantial welfare losses (about $260 million annual loss in consumer surplus). However, impacts on consumers outside California are minimal. Hog producer surplus impacts are small because California consumers pay higher prices that cover regulation costs.

The cost-effectiveness of Prop 12 as a means to stimulate more housing space for sows is reduced by the costs imposed on the downstream processing and marketing services because of the need for segregation, certification, and traceability. A direct farm subsidy for farrowing operations that met Prop 12 housing standards would expand housing from about twice as many sows as would Prop 12, at the same cost. My research documents how the form of regulation and where they are placed along the supply chain has important implications for cost-effectiveness.

Policy simulations often need appropriate demand parameters, and these are often not available for specific food products or product attributes. In Chapters 5 – 7, I developed estimates of demand parameters for selected carrot product attributes defined as organic farm production and fresh-cut processing practices.

Although carrots are a widely consumed vegetable, little research has explored carrot demand and especially the demand for organic or fresh cut carrot product attributes. Also, although fresh-cut produce has been important in the market for decades, little research is available on fresh-cut produce demand.

I conducted a series of large web-based surveys that gathered willingness to pay information from more than 350,000 respondents. In Chapter 5, I explained the survey process and documented the use of the responses and the associated demographic information. Food economists should be interested in the effectiveness of my simple survey design and the cost-effectiveness and timeliness of data collection.

For the results discussed in Chapter 6, respondents were shown a picture of one of four carrot packages and were asked to choose the most they would pay among several WTP intervals. I found that the share of respondents willing to pay for the offered package of carrots shown is much smaller for higher prices and the magnitude of the price response suggests that most consumers were unwilling to pay more than what they viewed as a prevailing price for the product pictured. I also found that with a single product shown, respondents indicated only small differences in willingness to pay for product attributes.

For the results discussed in Chapter 7, respondents were shown side-by-side pictures of two carrot packages that differed by a single attribute (either organic or fresh cut). For example, if one picture showed organic full-sized carrots and the other picture would show non-organic full-sized carrots. Each picture had a price attached. Respondents were asked to indicate which package they would buy at the indicated prices. When respondents faced a side-by-side comparison, they showed a strong significant positive median WTP for both organic and fresh-cut carrot packages. These results also show that a sizable share of the respondents is not willing to pay more for the organic or fresh cut products, and some respondents choose non-organic or full-sized carrots, even when prices offered are the same. These results are broadly consistent with market observations.

Another important finding is the robustness of the WTP estimates of carrot attributes. Willingness to pay estimates differ by age group and region, but not by the dates of the survey. Despite the economic, supply chain, and social disruption associated with the Covid 19 pandemic, respondents did not change the willingness to pay for carrot attributed from December 2019 through March 2021.