Essays on the economics and management of pet food

by

Lonnie Hobbs, Jr.

B.S., Prairie View A&M University, 2017
M.S., Kansas State University, 2019

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2023

Abstract

Pet food is an important component of the fast-growing global pet care industry, driven by increasing pet ownership and changing customer preferences. This dissertation contains three essays designed to provide research-based insights on the economics and management of pet food aimed at informing future research, product development, and marketing strategies in pet food. The objectives of the first essay are to identify the most relevant research gaps and research insight needed to inform raw materials, production, and marketing and distribution decisions in pet food industry. The methods include analysis of primary data from a survey of 76 pet food decision makers and systematic review of academic and non-academic literature. The second essay is aimed at examining factors that contribute to the presence of overweight or obesity in pets and related implications for pet food manufacturers. The methods involve analysis of primary data on feeding and exercise practices from a survey of 1,173 dog owners. The third and final essay is aimed at improving the understanding of pet food demand. Specifically, it utilizes a Generalized Exact Affine Stone Index (GEASI) model applied to panel data on 75,936 pet food buyers in 46 U.S. markets to test for the presence of pre-committed demand within pet food demand structure. Collectively these essays provide a range of new insights targeted at (i) informing future research in pet food economics and management, (ii) informing pet food industry strategies for developing and sustaining competitive advantage, and (iii) informing policy makers and industry stakeholders on how pet food customers respond to price changes.

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Chapter 1 - Introduction

The pet care industry has become an increasingly attractive industry in the last decade valued at $207 billion in 2020 (Statista, 2021a). In the U.S., 2020 pet care industry sales included: pet food ($9.4 billion), pet supplies ($25.9 billion), veterinary services ($40.7 billion), and pet services ($8.68 billion) (Waters, 2021). Expected pet care industry future growth is driven by rising pet ownership, rising per capita income among pet owners, and increasing acceptance of the humanization trend (pet owners view and treat pets as family) (Statista, 2021a). The scope and view of pets have evolved causing shifts in pet care offerings, and more specifically, the characteristics and types of pet food available to pet owners. Given the rising health consciousness of pet owners, there has been* an accompanying increase in the importance of nutritional benefits, product quality, and palatability in product offerings. Thus, the increased demand in pet food product offers unprecedented opportunities for pet-food companies, driving a need for innovative product and marketing strategies.

Recently, pet nutrition research has seen significant growth. Over the past two decades (2000-2019), a large portion of this work has been dedicated to identifying and testing ingredients to improve the nutritional benefits and value provided to pets through commercial product offerings. In addition, several studies have examined product processing and palatability characteristics for improved digestibility and functionality of various product forms (e.g., kibble, wet, dry, etc.). Although, there has been a significant increase in the nutritional studies to accompany the rise in demand for healthier products for pets, the body of work in other areas to add value to pet food decision makers does not follow the same pattern.

While the recent growth in the pet food industry has increased the interest of academic researchers, the volume of pet food economics literature still lags behind the growing needs of

decision-makers for several reasons (Hobbs, Jr., 2019). First, there is limited access to quality data needed to properly conduct economic analysis that may be valuable for industry decision makers. Although there is some publicly available expenditure data on pet food, in many cases most of the household characteristics are absent from the datasets to help describe the marginal level of spending on pets. There are entities that provide rich data sources on pet expenditure, yet there is often a significant financial cost associated with accessing such data. Second, much of the research conducted by pet food companies is proprietary, or comes from marketing agencies that sell data, and may not be publicly available for all decision makers. Those that conduct economic research internally may be disinclined to share findings outside of their organization. Although this is fair, decision makers within smaller companies that do not have resources to conduct internal economic research may be at a disadvantage. Third, the pet food industry has not received considerable attention from academic researchers in the economic space. Although it is not apparent why this is the case, it is possibly due to the lack of knowledge and awareness of the pet food space. Despite such factors, there is a need to increase the body of publicly available economic research in the pet food space to provide valuable insight to all pet food industry stakeholders.

The purpose of this dissertation is to offer valuable insights to the pet food industry on economic research needs, obesity-contributing factors, and the demand structure for pet food. This research will assist the industry in making informed strategic and policy decisions, enabling pet food companies to compete more effectively while enhancing the overall well-being of pets and their owners. The first essay identifies and highlights the most important, relevant, and current research needs for informing product and marketing decisions in the pet food industry; and highlights the gaps between current publicly available research insights and the desired

industry research insights of decision makers. It demonstrates the need for academic research insights to assist in decisions around quality of raw materials, processing methods/technology, and validation of product claims. The second essay uses primary survey data of subscribers to Whole Dog Journal to examine the role of pet owner feeding practices in pet obesity and to generate implications for the development and marketing of pet food products aimed at healthy weight management. The third and final essay assesses secondary scanner data of pet owners to estimate pet food demand elasticity measures and test for the existence of pre-committed demand among pet owners. Jointly, these essays contribute to the available pet food economic literature and provide research-based insights to assist stakeholders in product development, policymaking, and pet management practices.

Several methods based on the economic theory and empirical application used in previous studies have been employed in the succeeding chapters of this dissertation. In the identification of research insight needs (chapter 2), a needs assessment survey approach similar to that in business, medical, and training literature has been adapted and implemented. In chapter three, the theoretical modeling of previous pet obesity literature is proposed and tested using regression analysis. The final chapter borrows theoretical and empirical approaches from previous demand literature in other food areas, building a demand model for pet food. Demand functions and elasticities are then estimated using Circana panel data of pet owner purchases.

The body of publicly available research in the pet food field is growing as a whole but lacking on the applied economics side. With the growing demand for differentiated products, pet food economic research can prove useful to all pet food industry stakeholders. Furthermore, this dissertation utilizes applied economic approaches to help shape the conversation around pet food economic research and the value provided as more research transpires. The first essay provides

unique contributions to pet food academic researchers, by providing high priority research topics that yield valuable insight to meet pet food decision maker needs. Essay two contributes to the available literature that will assist pet food decision makers in product development and pet owner management practices. The third essay provides new findings and implications for pet food industry stakeholders, decision makers, policy makers, and academic scholars conducting pet food and animal nutrition research. More specifically, essay three benefits policy and decision makers by highlighting how pet food price changes can potentially affect customer preferences and purchasing patterns, allowing one to predict the potential impact of future pet food policies and external industry events.

This dissertation is divided into three remaining chapters. Chapter 2 (Essay 1) evaluates the current research needs of decision-makers in the pet food industry. It identifies common and unique research gaps expressed in academic and non-academic literature, as well as those expressed by pet food decision-makers. Chapter 3 (Essay 2) investigates feeding factors that are correlated with dog obesity among health-conscious dog owners. Chapter 4 (Essay 3) examines the current demand structure and the existence of pre-committed demand in dog food, specifically focusing on five animal-based protein categories. Dissertation survey instruments, and Circana data summaries are presented in the Appendix. Specifically, Appendix A presents the Survey Questionnaire for Needs Paper, Appendix B Pet Food Literature Reading List, Appendix C Questionnaire for Obesity Paper, and Appendix E summary of U.S. Dog Food Retail Market Average Prices.

Chapter 2 - Assessing Research Needs for Informing Pet Food Industry Decisions

2.1 Introduction

2.1.1 Background and Problem Statement

Growth in the pet food industry increased during the first two decades of the twenty-first century. Global sales of pet food went from less than $30 billion in 2000 to $53.9 billion in 2010, and to $102 billion in 2020 (Statista, 2021c). The industry growth has been fueled by higher disposable income, increased pet ownership, and growing demand for higher priced premium products. This rising demand is creating unprecedented opportunities for pet-food companies to capture the increase in profit potential in the market, driving a need for innovative product and marketing strategies to create or enhance competitive advantage in the market. An important pre-condition for designing and implementing effective product and marketing strategies is the availability of evidence-based insights to inform the decision-making process of pet food companies.

While the recent growth in the pet food industry has attracted increased interest of researchers in business, marketing, economics, and animal nutrition, the overall body of literature in this area is still limited compared to the needs of industry stakeholders (Evason et al., 2020; Prata, 2020). Traditionally, industry decisions are informed through analysis conducted by (i) in-house research teams, (ii) industry associations, (iii) external consultants and firms, and (iv) academic research institutions. Conventional channels through which these insights are being disseminated and accessed by industry stakeholders include internal reports, trade publications, and academic journals. The gap in research insights is likely the result of three primary factors. First, it is reasonable to assume that most of the research insights

generated by in-house capabilities and external consultants are (a) company-specific and (b) not widely available. Second, the research sponsored or generated by industry associations, while generalizable, tends to be limited in scope. Third, the research insights generated by university researchers and disseminated through academic journals, while publicly available, tends to be (a) disjointed across disciplines and (b) is likely to lag behind the current needs due to extended timelines of the peer-reviewed publication process, and dynamic changes in the pet food industry. Consequently, there is a need for a systematic assessment of the availability and the need of evidence-based insights and high-priority research required for informing product and marketing decisions and supporting the pet food industry growth.

There is literature suggesting a survey of industry representatives can help to identify problems faced by various companies and provide useful insight into the actual needs of decision makers (Depken & Zeman, 2018; Gilbert et al., 2010; Malavolta et al., 2013). It is beneficial for researchers to occasionally survey their stakeholders to monitor for new developments and make sure their research is focused on major problems of the target audience. Needs assessment surveys have been found to help determine the needs of industry in order to develop effective strategies and to provide technical assistance by land grant universities. More specifically, needs assessments helps to identify which groups are in need, the different types of needs, and severity of needs (Barron, 2009). This approach has been used in several fields including business, education, and extension; yet there are no such published studies in pet food.

2.1.2 Research Objectives

The purpose of this study is to identify and highlight the most important, relevant, and current research needs for informing product and marketing decisions in the pet food industry. Specific objectives include:

(1) Provide a comprehensive overview of the existing academic literature on production, marketing, and economics of pet food.

(2) Provide a comprehensive overview of the existing body of non-academic literature including trade publications and industry reports.

(3) Provide an overview of current research needs expressed by pet-food industry decision makers.

(4) Identify and highlight the gaps between the available research insights and the industry needs.

(5) Present and discuss the implications and directions for future research to support pet food industry growth.

To achieve these objectives, this study will utilize a combination of qualitative and quantitative research methods. Objectives (1) and (2) are achieved through an extensive literature review involving leading disciplinary and interdisciplinary journals in animal nutrition, agribusiness, marketing, and applied economics, as well as pet food industry reports and trade publications. Objective (3) is achieved by designing and conducting a survey of pet food industry decision makers involved in procurement of raw materials, production, and marketing. The survey design and methodology will draw insights from existing studies of research needs of decision makers in other industries (Depken & Zeman, 2018; Malavolta et al., 2013). The survey is designed to collect information on respondents demographic characteristics (e.g. education and

company size), area of responsibility (e.g. raw materials, production, marketing), frequency of decision making, perceived relative importance of research insights for informing decisions in raw materials, production, and marketing, primary sources for obtaining research insights, important challenges and key information gaps, as well as current and future product/market trends in pet food. Objectives (4) and (5) are achieved through a synthesis, analysis, and delineation of insights gained from objectives (1), (2), and (3).

The contribution of this study is threefold. First, it provides a comprehensive review of academic and non-academic literature on the pet food industry. Second, it identifies and describes specific needs for research insights from the perspective of actual industry decision makers. Third, it identifies and highlights the gaps in available research insights and the industry needs providing implications and direction for future research. There are two primary stakeholder groups who stand to benefit from the findings of this study: academics conducting research on pet food and animal nutrition, and pet food industry decision makers. The results of this study highlight high-priority areas for research in pet food, thus directing the future research towards high-impact topics resulting in enhanced economic return on public spending on research and outreach. In addition, there is potential to strengthen the relationship between pet food companies and academic researchers resulting in economic benefits through increased efficiency of pet food production and marketing, positively impacting pets, pet owners, and pet food businesses.

2.2 Methods and Data

2.2.1 Academic and Non-academic Literature Retrieval

To better understand the current state of academic literature on pet food, a thorough review is conducted to identify information gaps in three primary areas: raw materials, production, and marketing/distribution. This review examined top journals in both pet food/nutrition and agricultural economics, utilizing keyword combinations such as "pet food," "dog," "cat," "companion animal," and "animal food." Key words specific to each primary area are also included, such as "raw material," "ingredient," and "protein" for raw materials, "production," "processing," and "extrusion" for production, and "marketing," "purchasing," "distributing," "distribution," "consumer," and "supply chain" for marketing/distribution. Only research articles that included these key words in their title, abstract, and/or article keywords are selected and reviewed. The review examined journals such as the Journal of Animal Physiology and Nutrition, the Journal of Animal Science, and the Journal of Small Animal Practice for pet food/nutrition, and the American Journal of Agricultural Economics (AJAE), Applied Economics Perspectives and Policy (AEPP), the Journal of Agricultural Economics (JAE), and the International Food and Agribusiness Management Review (IFAMR) for agricultural economics. Due to the limited number of economics and management studies related to pet food, scientific search engines like Google Scholar, ProQuest, Scopus, AGRICOLA, ECONLIT, and Wiley Online Library are also included in the review to expand the reach for articles.

We also conduct a structured analysis of non-academic literature to uncover gaps and key questions in the areas of raw materials, production, and marketing/distribution. A similar keyword combination search, as used in the academic literature search, is conducted to

investigate top online publications related to pet food and nutrition. Publications such as Petfood Industry Magazine, Animal Wellness Magazine, Pet Age Magazine, and The Pet Gazette Magazine are examined using the keywords mentioned above. We also evaluate pet food industry reports from IBISWorld, Mintel Reports, and Statista to provide a comprehensive representation of the available non-academic pet food literature. For further details, please refer to the Appendix B -Table 5.1and for a detailed reading list of academic and non-academic literature (including governmental documents and reports).

2.2.2 Survey Data Sources and Study Items

A structured Qualtrics survey is administered to identify pet food decision maker needs. Survey respondents include professional attendees of the 2021 Pet Food R&D Showcase and the 2021 Pet Food Formulation for Commercial Production Course hosted by the Kansas State University (KSU) Pet Food Program, and 2022 Petfood Forum hosted by Watt Global Media. The Pet Food R&D Showcase is an annual workshop and conference designed to provide an opportunity to connect KSU expanding research presence with the needs of the pet food industry (Kansas State University Pet Food Program, 2018, 2021). Similarly, the Pet Food Formulation for Commercial Production Course is designed to provide pet food company employees an understanding of the different aspects of pet food formulation, ingredients, transportation, and storage as it relates to marketing effective pet food (Kansas State University IGP Institute, 2021). Attendees to the two virtual events consist of a variety of pet food industry professionals and stakeholders from large and small companies. Petfood Forum is the premiere Pet Food conference in North America. In addition to conference attendees, the Qualtrics survey link is

distributed to social media pet food groups, and through an article written by Watt Global media and published via social media.

2.2.3 Survey Design

The survey instrument is comprised of 20 questions concentrating on three focus areas: raw materials, production, and marketing and distribution. In each focus area, participants are asked to rate a list of factors based on the need for research insights to inform their company decisions, and to specify their primary source for obtaining research insights for each focus area. The research insight sources are in-house research, private consultants, industry association, university research, trade publications (e.g., industry magazines and websites) and other. In addition, open-ended questions are asked to identify the most important challenge and key information gaps related to each focus area.

Information on participant demographics, external research utilization, and industry trends are also collected. Demographic information is used to identify which areas of the pet food industry are represented in the survey. Demographic questions are related to education level, company size, primary area of decision making (raw materials, production, and marketing), and ranking of the three focus areas in terms of importance to the success of the company. The external research question gauges how likely the respondent (or respondent's company) will collaborate with various parties to obtain the research insights during the next 1-3 years. The collaborating parties include private consultants, university research, contract research organizations, and industry partners/ equipment suppliers. The external research question is formulated to identify where the industry players will obtain future research insights. We expect

to identify the most important needs for research insight of pet food industry players at this time, the current source of research insight, and the future source to obtain research.

2.2.4 Survey Data Characteristics

We begin by summarizing basic information of 76 decision makers by company size, whereas the company size refers to the number of employees at the company. Therefore, a small company reflects a pet food company with less than 100 employees, medium company has 100-1000 employees, and a large company employs more than 1,000 employees. Figure 2.1 presents a percentage breakdown of the survey respondents by company size. Although there are more respondents from medium sized companies, the representation by company size is proportional as the small, medium, and large company respondents represented 32%, 37%, and 31% respectively. In addition, we understand there may exist heterogeneity of research needs between companies represented in the small company category based on the number of employees and the available resources. For example, a company with three employees may experience different issues than a company with 75 employees. Therefore, we also subdivided small company responses based on three categories: 0-24 employees, 25-49 employees, and 50-99 employees. When taking this approach, we recognize that over 70% of the small company respondents are from companies with less than 25 employees (Figure 2.2). Thus, we suspect that the research needs highlighted by small companies is primarily reflective of the research needs of companies with less than 25 employees.

Figure 2.1. Industry Decision Makers' Response by Company Size

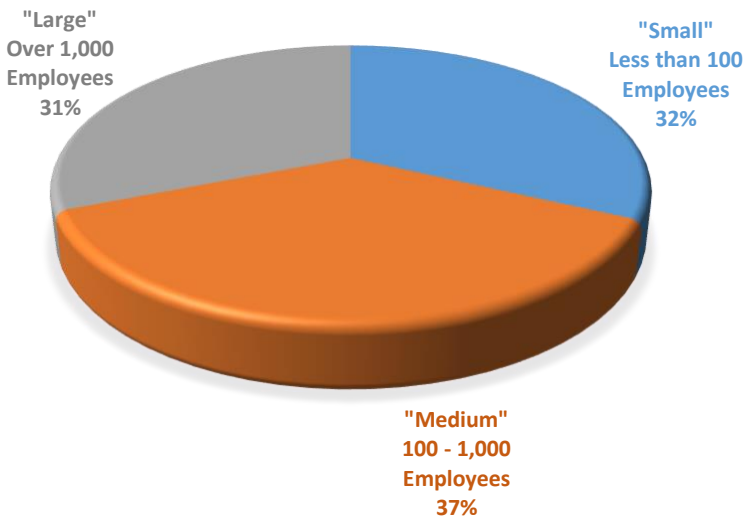


Figure 2.2. Small Company Decision Makers' Response by Company Size

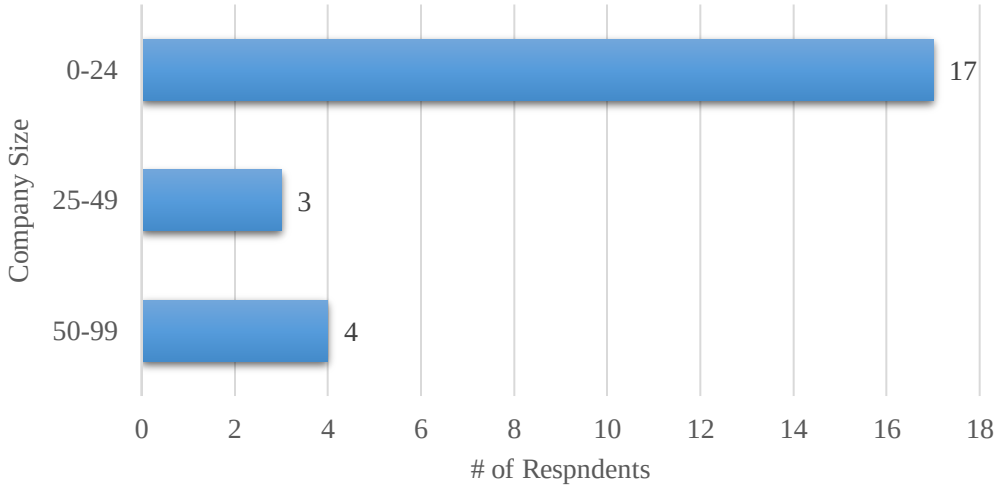


Figure 2.3 presents the decision makers' education level by company size. Of the educational degrees, a bachelor's degree is the most common level of education among all respondents. In addition, small and medium-sized companies exhibited similar education level trends with a bachelor's degree being the most common among survey respondents, followed by a master's degree or M.B.A. However, for larger companies, a Ph.D. or M.D. is the most reflective education level of the survey respondents closely followed by a bachelor's degree. A High school diploma/ GED is the least common education among all respondents and company sizes. There are also very few respondents with an associate degree for medium and large companies, but surprisingly more for small companies than Ph.D. or M.D. among small company respondents.

Figure 2.3. Industry Decision Maker Respondents' Education Level by Company Size

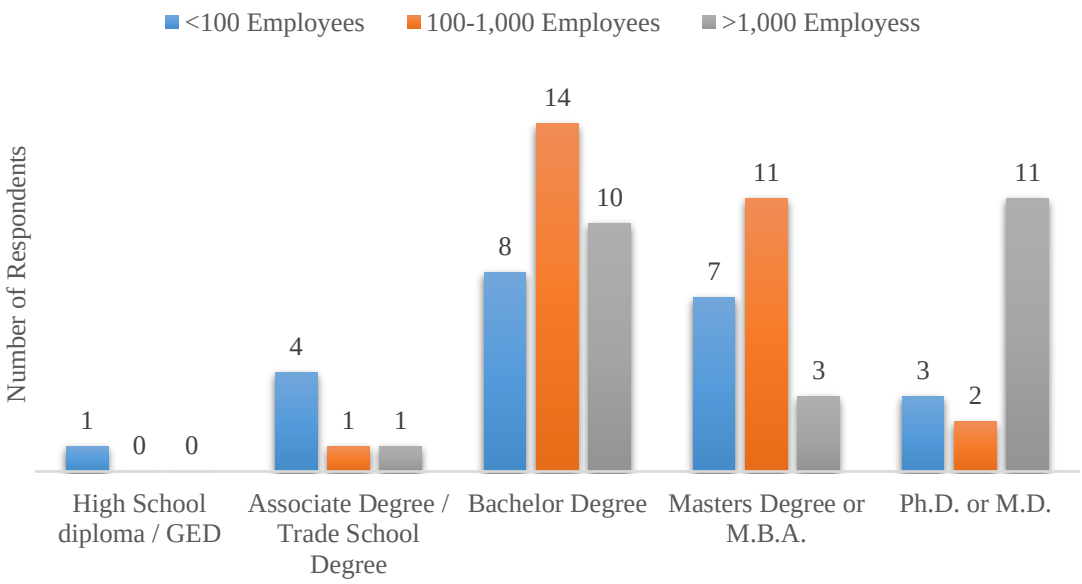
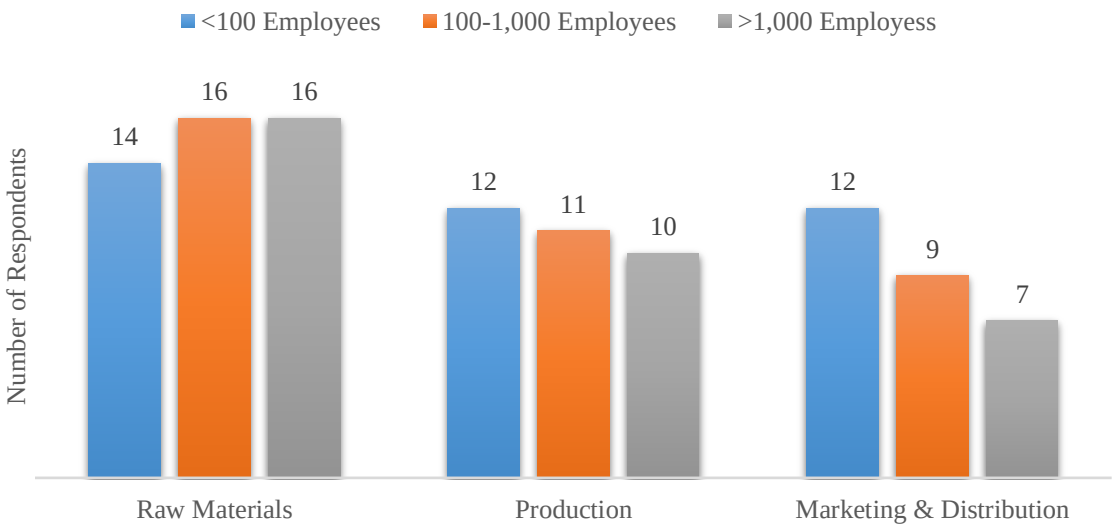


Figure 2.4. Industry Decision Maker Respondents' Primary Decision Area by Company Size



We also analyze the main decision-making area for each respondent to determine if the sample is representative of decision makers in each of the three focus areas (raw materials, production, and marketing) or if it is biased towards one area. By doing so, we better understand whether the research needs are actual needs of decision makers in each area or simply assumptions based on decision makers in other areas. Figure 2.4 summarizes the primary decision area by company size. For each company size, there are more primary decision makers in the raw materials category than in any other areas. We also observe a similar distribution for medium and large companies, with production being the second most common primary decision area and marketing and distribution being the least common. However, there are an equal number of small company participants who make primary decisions in the areas of production and marketing and distribution.

Overall, there is a proportional representation of primary decision makers in each area, providing comparable results among our sample size. It is important to note that some

respondents are primary decision makers in more than one area, and therefore the total number of respondents in Figure 2.4 exceeds our total sample size.

2.2.5 Method of Analysis

The analysis of survey data utilizes a combined quantitative and qualitative approach to identify research needs and information gaps in three primary areas: raw materials, production, and marketing/distribution. Survey participants are asked to rate four raw material factors, seven production factors, and six marketing/distribution factors on a scale of low research need (0) to high research need (10). The responses to each question are analyzed and discussed in reference to the company size. Factors with the highest mean rating are assumed to reflect the highest research need. Topics mentioned most in the open-ended responses are also considered important and relevant needs of the pet food industry. The research insights expressed by industry decision-makers are then compared and discussed in relation to the key gaps found in current academic and non-academic literature.

2.3 Results

2.3.1 Pet Food Raw Materials Research Needs

2.3.1.1 Pet Food Raw Materials Academic Literature

The academic literature on pet food raw materials focuses on identifying ingredients that enhance the nutritional value offered to pets (Aldrich, 2017; Buff et al., 2014; Hill, 2022). Researchers have used several approaches to address the issue of nutritious ingredient usage. Some have examined the benefits of protein sources, both animal and plant-based (Alexander et

al., 2020; Hill, 2022; Montegiove et al., 2021). Others have highlighted the safety of ingredients, such as the presence of mycotoxins and sodium (Boermans and Leung, 2007; Singh and Chuturgoon, 2017; Soffer et al., 2016), while others have investigated specialized ingredients (de Godoy et al., 2009; Hu et al., 2020; Michel, 2006). Each of these research articles attempts to address the need for nutritional ingredients to meet the basic animal requirements and improve the overall health of pets. Recent literature has also highlighted the rising demand for human-grade food for pet food due to the humanization trend. Pet owners now see and treat their pets like human members of the family, and this is reflected in the trends toward human food as pet food. Thus, further exploration is needed to understand the nutritional benefits of popular human food ingredients and identify alternative protein sources to meet the growing demand for specialized ingredients and high-protein diets (Buff et al., 2014; Hill, 2022; Samant et al., 2021).

2.3.1.2 Pet Food Raw Materials Non-academic Literature

Non-academic literature focused on pet food raw materials highlights the increasing use of human-grade ingredients, disruptions in the ingredient supply chain, and the need for transparency regarding plant- and animal-based protein sources. To respond to pet humanization and premiumization trends, market reports suggest that pet food companies should increase their use of natural and organic human-grade ingredients, alternative protein sources, or ingredients rich in nutritional value (Grand View Research, 2022; Mordor Intelligence, 2022). More recently, non-academic literature has emphasized the low availability of pet food ingredients due to supply chain disruptions in response to the global pandemic (Diment, 2022; Marketline, 2021; Pet Food Industry, 2022). Therefore, the remaining gaps in the non-academic literature include

identifying sustainable ingredient procurement/supply, increasing ingredient transparency, and identifying alternative protein sources.

2.3.1.3 Raw Materials Research Needs of Industry Decision Makers

Table 2.1 summarizes the results of research on raw material needs for companies of different sizes. The most urgent research need for raw materials, with a combined mean score of 8.01 among small, medium, and large companies, is the quality of raw materials. Respondents from all company sizes also rated the availability and consistent supply of raw materials as the second most important research need, with a combined mean of 7.28. Interestingly, the cost of raw materials and governmental regulations of raw materials showed the same combined mean score of 6.77 among all respondents, regardless of company size.

Table 2.1. Raw Materials Most Important Research Needs by Company Size

All Company Sizes					
	Mean	Min	Max	Std. Dev.	Count
Availability / Consistent supply of raw materials	7.28	0	10	2.46	76
Cost of raw materials	6.77	0	10	2.61	75
Quality of raw materials	8.01	0	10	2.44	75
Governmental regulations of raw materials	6.77	0	10	2.50	74
Other (Please specify)	9.21	7	10	0.97	14
<100 Employees					
	Mean	Min	Max	Std. Dev.	Count
Availability / Consistent supply of raw materials	7.09	0	10	2.71	23
Cost of raw materials	7.13	0	10	2.85	23
Quality of raw materials	8.30	0	10	2.38	23
Governmental regulations of raw materials	6.59	0	10	2.42	23
Other (Please specify)	8.75	7	10	1.50	4
100-1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Availability / Consistent supply of raw materials	7.96	3	10	1.88	28
Cost of raw materials	7.07	2	10	2.21	28
Quality of raw materials	8.54	3	10	1.82	28
Governmental regulations of raw materials	6.96	1	10	2.59	28
Other (Please specify)	9.50	9	10	0.55	6
>1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Availability / Consistent supply of raw materials	6.68	0	10	2.7	25
Cost of raw materials	6.08	1	10	2.76	24
Quality of raw materials	7.13	1	10	2.94	24
Governmental regulations of raw materials	6.71	2	10	2.56	24
Other (Please specify)	9.25	8	10	0.96	4

Regarding small companies, respondents ranked the cost of raw materials as the second most important research need on average, followed by availability / consistent supply of raw materials. In contrast, the medium company respondents expressed availability / consistent supply of raw materials as the second most important research need and cost of raw materials as

the third highest research need on average. However, respondents from both small and medium companies suggested governmental regulations of raw materials is the least important research need, whereas governmental regulations of raw materials are the second highest research need expressed for large company respondents. Availability / consistent supply of raw materials and cost of raw materials rank third and fourth respectively among the important research needs by decision makers from the large companies.

There are other primary needs for raw material insight expressed by respondents from each company size that are alternative to the given choices. Four of the small company decision makers signaled there are other raw material research needs, whereas two respondents listed functionality as their primary need for insight, and two others expressed a need for raw material innovations. Among the medium company respondents, items such as alternative raw material sources, novel ingredients, functionality, and sustainability of raw materials are expressed as high priority research needs. Similarly, large company respondents indicate items such as functionality, biofuels, purity, safety, and sustainability are important research needs.

2.3.1.4 Industry Decision Makers Raw Material Current Primary Source of Insight

Figure 2.5 presents the results of the primary source of research insight for raw materials utilized by each survey respondent. The survey results indicate that in-house research is the most common primary source of research around raw materials for the three company sizes. For smaller company respondents, the participants indicate that industry association is the second most common source of research insights in the area of raw materials. In addition, private consultant and university research tied for the third most common source to gather insight on raw materials. It is also important to note, there is one small company respondent who indicated the

information on raw materials insight is not available currently. Regarding medium sized companies, industry association and trade publications are indicated as the second primary source of gathering research information of raw materials. Likewise, private consulting and other sources of information are ranked as the third most common source of research insight on raw materials for medium sized company respondents. University research is the least common source of raw material research insight for respondents from medium sized companies. However, university research and trade publications tied for the second most common source for raw material research insight for large company respondents. Private consulting and industry association are the least common sources of insight for raw materials expressed by the large company decision makers.

Figure 2.5. Raw Materials Primary Source of Research Insight by Company Size

2.3.1.5 Raw Material Most Important Challenge

We assess the most important raw material challenge by summarizing of open-ended responses provided by the decision makers. As suspected, many respondents referred to current supply chain disruptions due to the recent pandemic. Consequently, there are three common challenges expressed across each of the three company sizes: availability of raw materials, consistency of raw material quality, and cost of raw materials. Regarding small company decision makers, more than 75% of respondents mentioned availability, consistency, and/or cost as the most important raw material challenge they currently face. The remaining small company respondents expressed challenges such as processing, competition with human food companies, and sourcing of organ meats.

Medium sized company decision makers also expressed availability, consistency, and/or cost as the most important challenges, as mentioned by more than 82% of medium company respondents. However, other challenges expressed included: supplier food standards, food safety standards, time consumption to verify new suppliers, and matching raw materials specifications. Following a similar trend, 70% of large company decision makers identified the three common challenges related to availability, consistency, and cost as the most important in the area of raw materials. In addition, other challenges highlighted are ingredient storage, approval for use in exotic species, innovation enablers, approval of AAFCO natural ingredients, and reliable data of ingredient proteins. As shown by the open-ended results, each of the company sizes face similar challenges due to supply chain disruptions. However, there exist some variation between the other challenges faced based on company size.

2.3.1.6 Raw Material Key Information Gap

Survey respondents are also asked to provide key information gaps in the raw material insights relating to their companies. Unlike the most important challenges response, there is noticeable variation between the responses based on company size. Regarding small company respondents, the key information gaps expressed are sustainability standards, price anticipation, ingredient interaction, misinformed labelling, and new raw material types. In contrast, medium company decision makers highlighted information gaps such as functionality of raw materials, information about food safety programs, nutrient profiles, regulatory differences between domestic and international products, and inadequate public understanding of raw materials. Key information gaps expressed by large company survey respondents are ingredient impact on product labelling, free paper options, one-for-one substitutions for raw materials, robust quality research on all ingredient types, government regulations on renewable fuels, raw material functionality, and threshold identification of proteins triggering allergic reactions.

2.3.2 Pet Food Production Research Needs

2.3.2.1 Pet Food Production Academic Literature

Current academic literature in the area of pet food production largely focuses on enhancing production techniques. Specifically, there is a consensus in the pet food production literature to address improved nutrient retention, product functionality, quality, and palatability of pet food during the extrusion process (Baller et al., 2021; Koppel et al., 2014; Morin et al., 2021; Tran et al., 2008). Several recent studies assessing the pet food production process suggest the need for identification and use of palatability and nutrient enhancers to increase the nutritional value of final pet food products (Baller et al., 2021; Hu et al., 2020; Morin et al., 2021). Other studies highlight the need to improve the efficiency, effectiveness, and safety of pet

food production while lowering production costs (Craig, 2021; Leiva et al., 2019; Soffer et al., 2016). Overall, the remaining gaps in the pet food production academic literature include approaches to improve the production process for increased nutrient retention and product safety (G. C. Aldrich and Koppel, 2015; Leiva et al., 2019; Samant et al., 2021).

2.3.2.2 Pet Food Production Non-academic Literature

The non-academic literature publicly available on pet food production currently focuses on identifying sustainable production practices, nutrient retention practices, and solutions to labor shortages. Industry publications and reports emphasize the need to improve the nutritional benefits and product safety of pet food while accommodating changing customer demands (Mordor Intelligence, 2022; Statista, 2021). Recently, several industry articles and reports have highlighted the need to address COVID-related production disruptions, such as ingredient and labor shortages (Beaton, 2022; Calderwood, 2022; Tyler, 2021; Vennetti, 2022). However, the remaining gaps expressed in the non-academic literature center around ways for pet food companies to improve nutrient retention, product safety, and ingredient transparency during the production process (Grand View Research, 2022, 2022; Statista, 2017, 2021).

2.3.2.3 Pet Food Production Research Needs of Industry Decision Makers

Table 2.2 reports the results of the production research insight needs expressed by survey participants. The overall research needs ratings provided for each of the seven factors ranged from 3.73 to 6.70 on average, as shown in Table 2.3. Of the three company sizes, there is a consensus that geography / location is the lowest factor of research need for pet food industry decision makers, expressed by the combined 3.97 mean for small, medium, and large company

respondents. In contrast, processing methods/technology ranked highest among all production factors for all company sizes combined with a 6.60 mean. Risk management is the only other factor with a combined mean greater than 6.0 as rated by all respondents. Decision makers identified governmental regulations and approaches for attracting talent as the third and fourth most important pet food production research needs with respective means of 5.90 and 5.64. Closely following talent attraction approaches, facilities and management methods/processes exhibited means of 5.59 and 5.51 respectively. However, the level of research need expressed for the remaining factors varied by company size.

Table 2.2. Production Most Important Research Needs by Company Size

All Company Sizes					
	Mean	Min	Max	Std. Dev.	Count
Processing methods/technology	6.60	0	10	2.31	72
Management methods/processes	5.51	0	10	2.44	71
Approaches for attracting talent	5.64	0	10	2.86	69
Risk management	6.23	0	10	2.51	71
Governmental regulations/compliance	5.90	0	10	2.82	71
Facilities	5.59	0	10	2.57	70
Geography / Location	3.97	0	9	2.60	70
Other (Please specify)	5.00	0	10	5.77	4
<100 Employees					
	Mean	Min	Max	Std. Dev.	Count
Processing methods/technology	6.68	2	10	2.10	22
Management methods/processes	5.50	1	10	2.46	22
Approaches for attracting talent	5.14	1	10	3.21	21
Risk management	6.55	1	10	2.42	22
Governmental regulations/compliance	5.95	1	10	2.73	22
Facilities	6.32	0	10	2.66	22

Table 2.2. Production Most Important Research Needs by Company Size (cont.)

Geography / Location	3.73	0	8	2.66	22
Other (Please specify)	3.33	0	10	5.77	3
100-1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Processing methods/technology	6.59	0	10	2.63	27
Management methods/processes	5.48	0	10	2.58	27
Approaches for attracting talent	5.52	0	10	3.11	27
Risk management	6.70	0	10	2.40	27
Governmental regulations/compliance	5.74	0	10	2.92	27
Facilities	5.48	0	10	2.46	27
Geography / Location	4.27	0	9	4.27	26
Other (Please specify)	10.0	10	10	-	1
>1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Processing methods/technology	6.52	1	10	2.19	23
Management methods/processes	5.55	1	10	2.36	22
Approaches for attracting talent	6.29	2	10	2.08	21
Risk management	5.32	1	9	2.61	22
Governmental regulations/compliance	6.05	0	10	2.92	22
Facilities	4.95	1	10	2.54	21
Geography / Location	3.86	0	9	2.78	22
Other (Please specify)	-	-	-	-	0

Regarding respondents from smaller companies, processing methods/technology received the highest rating on average of research insight need in production. Table 2.2 also denotes that processing methods/technology had a minimum rating of 2.00, whereas each of the other factors expressed by respondents from smaller companies received minimum responses of zero and one. Risk management and facilities closely followed the production research needs for small companies, as these are the only factors with a mean of 6.0 or higher expressed. Governmental regulations/compliance, management methods/processes, and attracting and retaining talent ranked fourth, fifth, and sixth respectively for research needs for small company respondents,

with means ranging from 5.14 – 5.95. Geography/location ranked lowest for smaller company respondents with a mean of 3.73. In addition, geography/location is the only factor expressed by small company respondents that did not receive a maximum response of 10, signaling a lower need for research than the other factors. Three small company decision makers indicate there are other important research needs outside of those provided. However, only one of the decision makers indicate the "other" need, in which they expressed that teamwork is the most important need for their company success.

Respondents from medium-sized companies commonly agreed on average that risk management has the highest need for research insight for the success of their company. In addition to risk management, processing methods/technology is the only other factor with an average rating greater than 6.0 for participants from medium sized companies, with means of 6.70 and 6.59 for risk management and processing methods/technology, respectively. Governmental regulations (5.78) and approaches to attract and retain talent (5.52) ranked as third and fourth highest need for research insight among medium sized company decision makers. Surprisingly, management methods and facilities had an equal mean of 5.48 as ranked by medium size company respondents. Geography/location ranked lowest among all factors with a mean of 4.27. One medium size company respondent identified nutritional value effect as the most important production research need for insight for the success of their company.

Regarding the responses from large company decision makers, the results indicate that processing methods/technology is the highest research need among the production related factors. Notably, approaches for attracting and retaining talent is rated as the second. Most important research need for large company respondents, closely followed by governmental regulations / compliance with respective means of 6.29 and 6.05. In addition, approaches to

recruiting and retaining talent displayed a minimum rating of 2.0, yielding the highest minimum rating among all production factors for large company decision makers. Management methods / processes and risk management are the only factors within the range of 5.0 – 5.9, with means of 5.55 and 5.32 respectively. Surprisingly, risk management is one of two factors with a maximum rating of nine instead of ten, which the other factors received. Facilities and geography/location received the lowest rating on average by the large company decision makers. Facilities received means of 4.95 and 3.86. Like risk management, geography/location also displayed a maximum rating of 9.00 by the large company decision makers, following a similar trend as reported by medium sized company respondents.

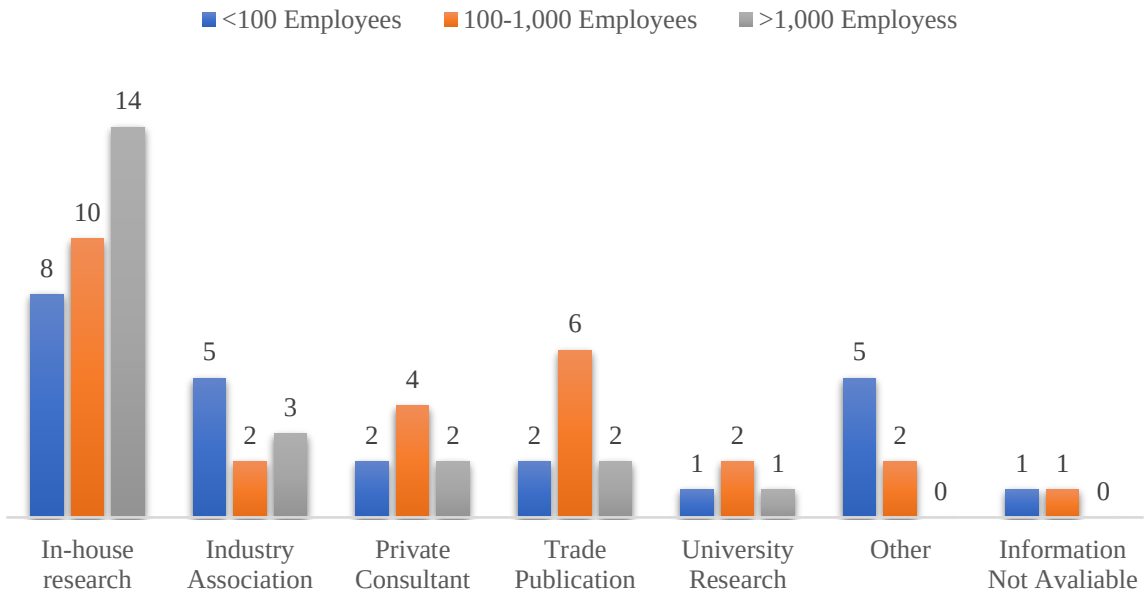
2.3.2.4 Industry Decision Makers Pet Food Production Current Primary Source of Insight

Figure 2.6 presents the results of the industry decision makers' current primary resource of production research insight. Following a similar trend as the raw material primary sources of research, In-house research is the most common source of production research insight among all company sizes. Regarding small companies, industry association and "other" tied for the second most common source of production insight, each of which are the primary source for five small company respondents. Private consultant and trade publication both are represented by two respondents of the small companies who utilize them as the primary source of production insight. There is only one small company respondent who utilize university research as a primary source of insight. Likewise, one respondent signaled that this information is not available to small company decision makers.

Examining the results of the medium sized company respondents, we see that trade publication is the second most common primary source for decision makers to access production

research insight, as expressed by six respondents. Closely following trade publication, the use of private consultants is the third most common primary source for medium sized companies to gain research insight into production. Industry association, university research, and "other" are the primary sources of insight as signaled by two medium sized respondents. Notably, one medium sized company decision maker expressed that the information is not available for them to access. Regarding large company respondents, industry association is the second most common primary source of insight selected, following a similar response to the small company decision makers. Bothe private consultant and trade publication tied for the third most common source of insight for large company respondents, each with two responses. Lastly, university research is the least common primary source of production insight indicated by the large company decision makers, with only one respondent expressing this source as their primary source of insight. It is also noteworthy that there are no large company respondents who selected "other" as their primary source, or information not available was indicated by the respondents.

Figure 2.6. Production Primary Source of Research Insight by Company Size



2.3.2.5 Pet Food Production Most Important Challenge

Survey respondents provided qualitative insight into the most important production challenges they are currently facing. As suspected because of the recent pandemic, challenges such as labor shortages, production time, and safety/sanitation requirements are commonly mentioned among each of the three company sizes. However, there is some variation among the other challenges mentioned. For instance, small company respondents indicate issues such as production capacity, identifying equipment manufacturers, and machinery needs for specialized product production (such as form and freeze-dried products). In contrast, medium sized company decision makers highlighted issues regarding product quality consistency, acceptance of new production approaches, rendering affects, and facilities to meet safety requirements. Regarding survey respondents from large companies, the most important challenges are scaling production to fit customer needs, post extrusion spray technology, production capacity, and technology adoption.

2.3.2.6 Pet Food Production Key Information Gap

Several decision makers across all company sizes indicate a common information gap in the form of new/innovative processing techniques designed to improve production efficiency. However, many of the other information gaps identified differed by company size. Small company respondents indicate the key information gaps are getting information from co-packers, regulatory interpretation, consumption rate information, and lack of dog and cat academic focused studies. Regarding medium company decision makers, the key information gaps mentioned are lack of production strategy insight/literature, custom equipment supply and maintenance, forward planning information for production, grind size information, and communication across plants. In contrast, large company decision makers identified key gaps in vitamin stability, employee training, data to drive decisions, academic literature on pet food production, and agility/flexibility of production scheduling to meet customer demands.

2.3.3 Pet Food Marketing & Distribution Research Needs

2.3.3.1 Pet Food Marketing & Distribution Academic Literature

Academic literature on pet food marketing and distribution primarily focuses on understanding customer purchase behavior and factors that affect purchasing decisions. Initially, these studies aimed to identify external forces that motivate pet purchasing decisions, such as the relationship with pets, family and demographic differences, and brand loyalty (McNicholas et al., 2005; Purewal et al., 2019; Schwarz et al., 2007). More recently, the focus has shifted to identifying specific product attributes and customer perceptions to understand demand preferences (Hobbs, Jr., 2019; Koppel, 2014; Koppel et al., 2018; Kwak and Cha, 2021). Pet

owners often align their personal dietary and ingredient preferences with their purchasing decisions for their pets (Statista, 2021a). As a result, pet food marketing academic literature has also emphasized the importance of product labeling, transparency, and regulations to inform marketing strategies and capitalize on the similarities of human and pet food demand (Antúnez et al., 2013; Hobbs, Jr., 2019; Lemke et al., 2015). However, many questions remain unanswered about predicting and efficiently meeting future customer preferences derived from humanization and premiumization trends.

2.3.3.2 Pet Food Marketing & Distribution Non-academic Literature

There is a wide range of non-academic literature focused on marketing and distributing pet food. Market reports from a large portion of the pet food industry provide insights about customer behavior, preferences, industry sales, and market forces that guide future industry forecasts. The consensus of this literature suggests the need for research on how to effectively communicate product value to customers. In addition, non-academic literature consistently emphasizes the importance for pet food companies to market specific product attributes desired by customers and adapt to changing purchasing habits (e.g., online shopping, automatic purchasing) to increase product sales (Statista, 2021c; Waters, 2021). Remaining information gaps in non-academic literature include promoting clean labeling, understanding purchasing decisions, and predicting future customer behavior.

2.3.3.3 Pet Food Marketing & Distribution Research Needs of Industry Decision Makers

Industry decision makers are also asked to identify the most important research insight need to inform marketing and distribution decisions. The survey participants are asked to individually rate six marketing and distribution factors from low research need (0) to high research need (10). The seven factors include: market and competitor intelligence, attracting and retaining customers, forecasting consumer demand, forecasting consumer tastes and preferences, coordinating supply chain and distribution, and validation of claims. There is also an "other, please specify" option available to each respondent. Results of the marketing and distribution research needs are reported below in Table 2.3.

Table 2.3. Marketing & Distribution Most Important Research Needs by Company Size

All Company Sizes					
	Mean	Min	Max	Std. Dev.	Count
Market and competitor intelligence	6.84	0	10	2.26	69
Attracting and retaining customers	6.52	0	10	2.59	69
Forecasting consumer demand	6.65	0	10	2.63	66
Forecasting consumer tastes and preferences	6.86	0	10	2.60	69
Coordinating supply chain and distribution	6.50	0	10	2.68	68
Validation of claims	6.78	1	10	2.64	67
Other (Please specify)	6.67	0	10	5.77	3
<100 Employees					
	Mean	Min	Max	Std. Dev.	Count
Market and competitor intelligence	7.10	2	10	2.26	21
Attracting and retaining customers	6.91	0	10	2.71	22
Forecasting consumer demand	6.29	0	10	2.85	21
Forecasting consumer tastes and preferences	6.77	1	10	3.01	22
Coordinating supply chain and distribution	5.86	1	10	2.77	22
Validation of claims	6.24	1	10	2.90	21
Other (Please specify)	10.00	10	10	-	1

Table 2.3. Marketing & Distribution Most Important Research Needs by Company Size (cont.)

100-1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Market and competitor intelligence	6.68	2	10	2.19	25
Attracting and retaining customers	6.52	1	10	2.50	25
Forecasting consumer demand	6.96	0	10	2.35	24
Forecasting consumer tastes and preferences	6.96	3	10	2.24	25
Coordinating supply chain and distribution	6.83	2	10	2.20	24
Validation of claims	6.88	1	10	2.73	25
Other (Please specify)	10.00	10	10	-	1
>1,000 Employees					
	Mean	Min	Max	Std. Dev.	Count
Market and competitor intelligence	6.78	0	10	2.41	23
Attracting and retaining customers	6.14	0	10	2.62	22
Forecasting consumer demand	6.67	0	10	2.80	21
Forecasting consumer tastes and preferences	6.73	0	10	2.66	22
Coordinating supply chain and distribution	6.77	0	10	3.07	22
Validation of claims	7.19	3	10	2.29	21
Other (Please specify)	-	-	-	-	0

The most important research need for marketing and distribution varied by company size, as expressed in Table 2.3. However, the combined results for all company sizes reveal that forecasting consumer tastes and preferences (6.86) is the highest need for research to assist in pet food marketing and distribution decisions. Market and competitor intelligence (6.84) and validation of claims (6.78) are also expressed as higher needs for research insights among all respondents on average, respectively ranking them as second and third most important marketing and distribution research need. Forecasting consumer demand (6.65), attracting and retaining customers (6.52), and coordinating supply chain and distribution (6.50) are rated as the lowest research need on average when all company responses are jointly analyzed. Yet, this is not the case for the average response when analyzed by company size.

Pet food decision makers from small sized companies rated market and competitor intelligence as the most important research need with a mean rating of 7.10. However, attracting and retaining customers closely followed the market and competitor intelligence research need with a 6.91 rating on average. Small company respondents ranked forecasting consumer tastes and preferences (6.77) as the third most important research need, followed by forecasting consumer demand (6.29) which ranked fourth and validation of claims (6.24) ranked fifth. Coordinating supply chain and distribution (5.86) ranked last of the marketing and distribution factors for small companies as it is the only listed factor with a mean rating of less than 6.0. One small company respondent who listed an additional research need other than the six provided factors; identifying customer reviews and customer ratings as the most important research need with a 10.0 mean.

Regarding medium sized company decision makers, forecasting consumer demand and forecasting consumer taste and preferences are tied for the most important research need, both receiving mean ratings of 6.96. However, forecasting consumer tastes and preferences received the highest minimum rating among all factors. Validation of claims and coordinating supply chain and distribution factors closely ranked as the third and fourth most important research need with respective means of 6.88 and 6.83. Respondents ranked market and competitor intelligence (6.68) fifth most important research need, followed by attracting and retaining customers (6.52) which is expressed as the lowest need for research insight among medium sized company decision makers. In addition, one medium sized company respondent highlighted customer-purchasing trials as the most important need for research insight for company success.

The rankings for most important marketing and distribution research need for large company decision makers identified validation and claims as the most important need for

research insight, with a 7.19 average rating and a minimum rating of 3. Market and competitor intelligence (6.78) ranked as the second most import research need, closely followed by coordinating supply chain and distribution, which ranked third with a 6.77 mean. Large company respondents expressed forecasting consumer tastes and preferences, and forecasting consumer demand as the fourth and fifth most important research need with means of 6.73 and 6.67, respectively. Like the medium size company respondents, attracting and retaining customers is rated as the least important research need for large company pet food decision makers with a mean of 6.14.

2.3.3.4 Industry Decision Makers Marketing & Distribution Current Primary Source of Insight

Figure 2.7 presents the current primary source of marketing and distribution research insight by company size. As noted in the figure, In-house research is the most common primary source to gain insight to guide marketing and distribution decisions in each of the three company sizes. Regarding small company respondents, there are ten of the twenty-two respondents who indicate In-house research as their current primary source for marketing and distribution research insight. Trade publications is listed as the second most common source of insight by small companies, closely followed by industry association, which is ranked third most common source. Private consultant and "other" source both tied for the fourth most common source of marketing and distribution insight among the small company respondents, both of which had only one respondent. Notably, there are no small company respondents to indicate university research as their primary source of insight, or the information is not available to their company.

Examining the responses of medium sized decision makers, we see that In-house research is the most common source of insight closely followed by trade publications with ten and eight

respondents respectively. Surprisingly, there are three respondents from medium sized companies who indicate the information on marketing and distribution is not available to assist in informing their decisions. In addition, “other” sources are the third most common source of marketing and distribution insight for the medium-sized company decision makers. Industry association, private consultants, and university research is indicated as the primary source of research insight by only one respondent for each source. It is also noteworthy that medium sized company respondents are the only respondents to utilize university research as the primary source of marketing and distribution research insight.

The primary source of insight for marketing and distribution decisions for large companies follows a very similar trend as indicated by production insights of large companies (Figure 2.7). More specifically, large company decision makers indicate that In-house research is the most common primary source of research insight, and industry association the second most common primary source. Similar to production primary source of insight, private consultant, and trade publication both tied for the third most common source of research insight to inform marketing and distribution decisions for large company decision makers. Only one large company respondent indicate they use “other” sources as their primary source of research insight for marketing and distribution decisions. Lastly, neither university research nor information not available is indicated by the large company respondents.

Figure 2.7. Marketing & Distribution Primary Source of Research Insight by Company Size

2.3.3.5 Pet Food Marketing & Distribution Most Important Challenge

When examining the qualitative responses of most important challenges related to marketing and distribution, it is apparent there are some similarities and differences among the different company sizes. Yet, validation of claims is a challenge expressed by decision makers across the three company sizes. Regarding small company marketing and distribution challenges, there are many different factors mentioned, such as: driver shortages and cost, validation of claims, understanding demographical needs of customers, positive customer reviews, shelf space, and attracting general practice veterinarians. In contrast, medium sized company respondents expressed challenges with growing market share, acquiring new customers, product adoption among core customers, validation claims, lack of data for forecasting, lack of research, and AFFCO restrictions. However, validation of claims is the most commonly mentioned problem among medium company decision makers. The most common important challenge expressed by large company decision makers is identifying how to meet the changing customer needs. Other

problems highlighted are logistics of production and marketing locations, telling product story, flow of supply chain, and validation of local claims.

2.3.3.6 Pet Food Marketing & Distribution Key Information Gap

According to pet food industry decision makers, limited data availability is a key marketing and distribution information gap across all company sizes. There are also other key gaps expressed that varied by company size. Small pet food decision makers highlighted information gaps in raw food marketing standards, lack of consumer survey and trends overview, and expected normalization of cost. On the other hand, medium sized company respondents identified key gaps in market segmentation, marketing differentiation strategy, inexperienced personnel, and customer complaints. Key information gaps expressed by decision makers from large companies included forecasting customer preferences for ingredient claims, cross-functional resources, company selection and use in publications, and industry alignment with validation of claims.

2.3.4 Pet Food Current & Future Trends

Further, we analyze the most important product/market trend in the pet food industry currently. According to small company decision makers, the most common trend identified is use of raw pet food, and humanization among pet owners. Other current trends expressed include natural, addressing canine DCM in grain-free foods, availability of turkey, food safety, nutrition, and minimally processed foods. Similarly, humanization is the most frequently expressed trend among medium company respondents. Medium company decision makers also expressed trends such as fresh, grain-free, sustainability, and product and packaging innovation. In contrast, there

is a greater consensus of the current product/market trend among pet food decision makers from large companies. In fact, 41% of large company respondents identified sustainability as the most current trend facing the pet food industry. In addition, 27% of decision makers from large companies highlighted humanization as the most current trend. Other trends expressed by large company respondents included grain free, consumer education, premiumization, and alternative proteins.

To gauge the respondents' thoughts for the future of the pet food industry, we asked each decision maker to identify the most important problem or challenge of the industry over the next 5-10 years. There is an overwhelming consensus among each of the three company sizes identifying sustainability of raw materials as the most important challenge in the near future. However, there is some variability in the other challenges mentioned based on company size. Challenges identified by small companies included access to nutritional data, product formulation, and demand for alternative protein sources. In contrast, respondents from medium sized companies expressed concerns for extending product shelf life, demand for human grade products, and WIE (water, ingredients, and energy) concerns.

2.4 Discussion

There is a general alignment among the common research gaps identified in academic and non-academic literature, as well as in the opinions of pet food industry decision makers. The overarching research needs expressed in each of the three key areas - raw materials, production, and marketing and distribution are similar. This suggests that both pet food literature (academic and non-academic) and industry decision makers are responding to the driving factors within the pet food industry. Specifically, the needs expressed by all three sources are direct responses to

the overarching pet food industry drivers of growing sales, rising pet ownership, and increased demand for specialized premium products due to humanization. The term "humanization" refers to pet owners now viewing and treating their pets as human members of the family (Cambridge University Press, 2021). Although there is general agreement regarding the research needed to address industry problems, there are unique key gaps expressed by industry decision makers in each primary focus area. Table 2.4 summarizes the common and unique pet food research gaps expressed in academic and non-academic literature, and industry decision makers.

Table 2.4. Common and Unique Research Gaps in Pet Food

	Academic	Non-Academic	Industry Decision Makers
Raw Materials			
Common gaps	• Use of human-grade ingredients • Identify alternative protein sources	• Use of human-grade ingredients • Identify alternative protein sources	• Use of human-grade ingredients • Identify alternative protein sources
Unique gaps		• Sustainable supply proteins • Transparency of protein ingredient sources	• Improved ingredient nutrient profiles • Sustainable supply of natural ingredients
Production			
Common gaps	• Nutrient retention during extrusion • Improve production safety	• Nutrient retention during extrusion • Improve production safety	• Nutrient retention during extrusion • Improve production safety
Unique gaps	• Identifying natural nutrient and palatability enhancers	• Addressing labor shortages	• Addressing labor shortages • Production strategy insight/literature • Production risk management
Marketing & Distribution			
Common gaps	• Forecasting customer demand and preferences	• Forecasting customer demand and preferences	• Forecasting customer demand and preferences
Unique gaps	• Marketing strategies to benefit from humanization trends	• Clean labelling promotion • Online purchase decision factors	• Validation of labelling claims • Market & competitor intelligence due to limited data

There is a consensus among three sources about the need to improve the quality and supply of raw materials, increase ingredient transparency, and identify alternative proteins for use in pet food. This study proposes three potential high-value areas for future academic research. First, researchers should examine unique plant and/or insect species as potential protein sources for pet food products. The current animal-based proteins used in pet food are by-products of human food production, and the trend of increased animal-based proteins usage in pet food production currently outpaces the rate of animal protein supply (Hill, 2022). Thus, identifying alternative protein sources can help meet the rising protein demand. Second, future research should examine the use and safety of human-grade ingredients to improve the quality of raw materials. The use of human-grade ingredients has the potential to increase the nutritional value of finished pet food products. However, packaging and handling measures must be improved to prevent safety concerns (such as increased toxins, foodborne illness, etc.) (Leiva et al., 2019). Lastly, pet food researchers should identify ways to improve ingredient traceability and potential benefits of local ingredient usage in pet food. Due to the increase in health-conscious pet owners, there is a rising demand for transparency of pet food ingredient usage and sourcing (Bloom, 2020). Research efforts that can help simplify the flow and traceability of raw materials through the pet food supply chain can address concerns with traceability and ingredient supply/availability.

The literature analysis and input from decision makers suggest that there is potential for high-impact academic research focused on processing methods and product functionality in the pet food industry. Firstly, there is a continuous need for research to enhance the extrusion process and increase nutrient retention. During the extrusion process, pet food undergoes extensive heat for cooking and drying, which results in vitamin loss, protein denaturation, and

loss of other nutritional factors (Tran et al., 2008). Therefore, there is a need for research focused on identifying alternative processing methods and/or natural nutrient enhancers to improve nutrient retention during extrusion. Secondly, studies should be conducted to identify and test natural palatability-enhancing agents to improve the palatability and functionality of pet food. Product functionality and palatability depend on various factors, such as product formulation, heat processing, raw material freshness and stability, and product packaging. Hence, identification of effective agents to improve product formulation, design, and packaging has the potential to improve perceived product appeal and benefits for pet food customers. Thirdly, there is a lack of literature focused on talent acquisition and development in the pet food industry. Labor shortages in pet food have become problematic due to the recent pandemic (Beaton, 2022; Tyler, 2021). Therefore, future research findings should guide recruitment and training techniques to increase the supply of qualified labor to meet the operational needs of pet food companies.

This study proposes three potential high-impact research directions aimed at addressing the primary marketing and distribution research needs of pet food decision makers. First, small and medium-scale pet food manufacturers have expressed a distinct need related to demand forecasting and consumer studies. Pet food demand is expected to continue to rise and evolve over the next decade due to factors such as pet ownership and disposable income. Proper understanding of pet food demand structure can help decision-makers and policymakers predict customer responses to industry forces. Second, there is a significant gap in the literature regarding the understanding of pet food purchasing decisions. As pet owners embrace the humanization trend, preferences for specialized product attributes have increased. Future research should identify high-priority attributes and ingredient preferences and enhance customer

knowledge of ingredient and attribute benefits to align pet food product offerings with customer demand. Lastly, academic researchers should provide insight to help pet food companies improve their e-commerce offerings, services, and marketing strategies effectively. The presence and acceptance of online shopping in pet food have increased significantly since the global pandemic, resulting in increased online shopping and demand for automatic purchasing services. Due to the ease of product comparison and increased competition in the e-commerce space, research focused on online pet food marketing strategies holds high value.

2.5 Conclusion

Although the pet food industry has experienced recent growth, the economics literature on pet food still lags behind the growing needs of decision-makers. This study aims to fill that gap by using primary data from industry decision-makers and executives to identify the research insight needs for informing decisions in raw materials, production, and marketing, as well as the current primary sources for obtaining such insights. Additionally, we conduct an extensive review of academic and non-academic literature to compare with the actual insight needs expressed by pet food industry decision makers.

Overall, the results indicate a general alignment in research insight needs among the three sources in the areas of raw materials, production, and marketing and distribution. However, we found a greater alignment between the insight needs of industry decision makers and those expressed in non-academic literature, whereas there may be a potential time delay between actual industry needs and those expressed in academic literature. Nevertheless, the results show that small and medium companies perceive higher value from academic research, which may be attributed to access to resources. Moreover, university research is useful for addressing pet food

decision makers regarding raw materials but is not widely used to gain insights into production and marketing/distribution decisions.

This study has the potential to identify new high-priority research areas and specific questions related to pet food. Academic researchers can fruitfully exploit these areas, resulting in high-impact research outcomes that align with the specific research needs of industry decision-makers. This study can also benefit industry stakeholders by (a) providing a systematic compilation of insights from existing literature, easily accessible by managers and decision-makers, and (b) highlighting high-priority research areas to inform industry associations' efforts and requests for research proposals. Managers and decision-makers can gain insights into their counterparts' important research needs, providing awareness of future industry problems and challenges affecting the pet food industry. We suggest that future academic research should focus on aligning current research topics with projected industry problems to account for publication time delays. This research provides insight into several issues that pet food industry decision-makers expect the industry will face over the next 5-10 years. Addressing these issues is likely to produce valuable insights from academic research, given that the industry will face the problem at the time of publication of the academic manuscript.

There are three primary limitations of this study: a relatively low sample size, a lack of geographical information, and possible heterogeneous interpretation of the presented factors for research insight. Although the sample provided adequate information regarding the needs of pet food decision makers, increasing the sample size of respondents could potentially increase the representation of decision maker needs. In addition, we did not include a location question in the survey to prevent identification of the survey respondents. However, geographical information could assist in determining if the research needs are geographically related. Lastly, the presence

of heterogeneity in question interpretation is a common concern among qualitative survey methods, and we suspect it also occurred in this study. Given the vagueness of the answer choices, we suggest that future researchers collaborate and discuss with industry decision makers to identify how to assess future research directions. This will ensure that the insights provided in future research projects provide value in assisting pet food companies.

Chapter 3 - Pet Obesity and its Causes: Implications for Business Innovation in Pet Food Development and Marketing

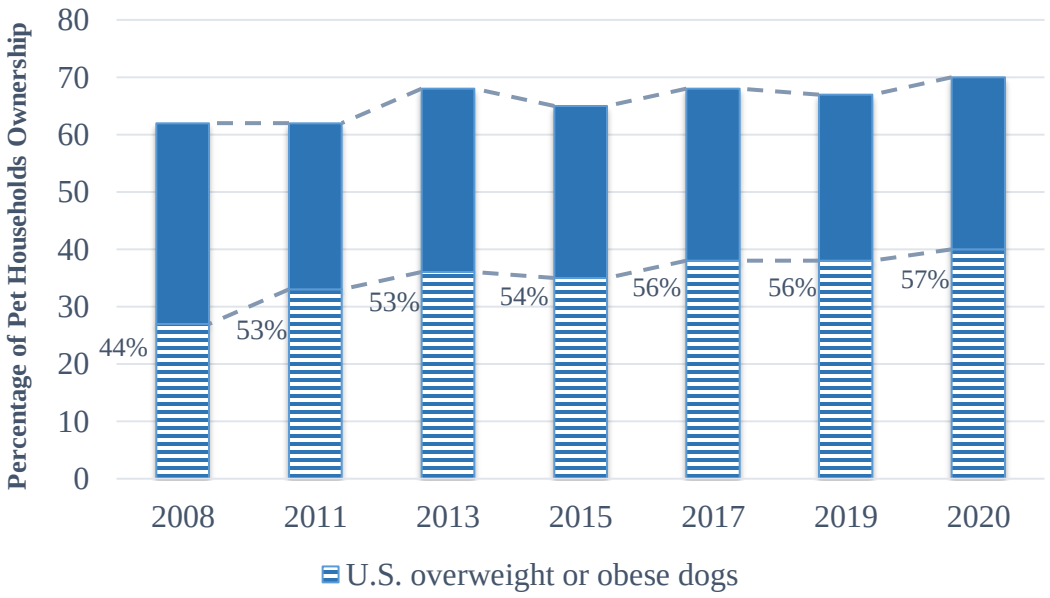
3.1 Introduction

3.1.1 Background and Problem Statement

The pet food industry is a rapidly growing global industry valued at $136 billion in 2022, with expected future growth driven by rising pet ownership, increasing disposable income, and the humanization trend (pet owners view and treat pets as family) (Statista Consumer Market Insights, 2023). With over 70% of US households owning a pet, there is a growing concern about pet obesity, as the number of overweight and obese pets has been steadily increasing (Figure 3.1) (Waters 2021; Statista 2021a). This is a particularly acute problem for dogs, as overweight and obese dogs constitute over 50% of the US pet dog population (American Pet Products Association, 2021). This has important implications for pet owners, pet food industry stakeholders, and the society in general. The growing obesity trend in companion animals indicates disproportionate calorie balance, most likely resulting from food type/composition, overfeeding, insufficient exercise, or a combination of these factors (Chandler, 2018). Pet obesity trend has a negative impact on the pet owners and industry stakeholders. Pet owners of overweight and obese pets potentially incur increased maintenance costs (i.e., veterinarian and grocery costs) and psychological impact from the emotional stress from the worry of their pets' health issues. In addition to a reduced life expectancy of overweight or obese pets by up to 2.5 years, owners also incur an additional $2,000 per year in healthcare spending on average due to obesity related health concerns (American Veterinary Medical Association, 2019; Bomberg et al., 2017). Obesity in pets can also have a negative impact on pet food companies due to shorter customer lifecycles and decreased long-term sales from reduced life expectancy in animals.

The rise in pet obesity provides potential opportunities for pet food product differentiation aimed at weight management in pets. While the research on pet obesity has grown recently, there is no sufficient research to help inform product innovation, design, and marketing decisions of pet food companies (Coy et al., 2021). Consequently, many questions remain unanswered regarding the role of pet food marketing and product design in exacerbating or mitigating pet obesity.

Figure 3.1. U.S. Pet Ownership and Overweight/Obese Dogs



Source: Statista. (2021). Pet ownership in the U.S.

In light of these concerns and potential market opportunities, it is important for pet food companies to be proactive. This could involve developing new products specifically designed to promote a healthy weight for pets, as well as more effective marketing campaigns to educate pet owners on the importance of proper feeding and exercise for their pets. By taking a proactive

approach to this issue, pet food companies can help ensure the health and well-being of pets, while also tapping into a new profit potential in their industry.

New entrepreneurial ventures and product innovations focused at promoting healthy body condition in pets has a potential to not only help address an important societal problem but also provides a valuable business opportunity in the growing pet food industry. In human food, a rise in product innovation (e.g., low calorie, low fat, smaller portion size, etc.) to control calorie intake and weight management has provided value and profit for human food companies while contributing to efforts in mitigating obesity problem in society. Mirroring this trend, the pet obesity management market was valued at $626.99 million in 2018 and is expected to continue its growth driven by the humanization trend, increasing pet owner preference for premium products, and the emulating effect of human food trends in pet food (Grand View Research 2019). Tapping into the full potential of these trends requires innovation in pet food product and marketing strategies; however, an important pre-condition for it is a deeper understanding of the factors contributing to pet obesity.

3.1.2 Research Objectives

The purpose of this study is to generate insights for informing product innovation, design, and marketing strategies of pet food companies aimed at promoting healthy weight management and feeding habits of pet owners. Specific objectives include: (a) examining the factors contributing to pet obesity (e.g., feed type, nutrition profile, amount, frequency), and (b) present implications for pet food innovation, development, design, and marketing aimed at promoting healthy weight and well-being in companion animals.

The analysis is based on unique cross-sectional primary data from a survey of 1,173 dog owners subscribed to Whole Dog Journal. The data provides information on feed/treat type, amount, frequency, as well as the dog's characteristics and activity level. The conceptual framework is based on a calorie-in-calorie-out model, which allows for a relatively accurate estimation of the effects of various feed and treat attributes and feeding behavior on a pet's body condition. Other information analyzed includes dogs' genetic pre-disposition, reproductive management, and owner characteristics. An econometric model is specified and estimated to gain insights on the predictive effect of each of these factors on pet body condition. The estimation results are synthesized into actionable insights aimed at informing the development and launch of innovative pet food products conducive to healthy weight management in companion animals.

The research findings presented in this paper have the potential to inform decisions of pet food companies and pet owners, and extend the pet management literature for academic and private researchers in the pet industry. The findings in this study may potentially inform product innovation and marketing strategies providing opportunity to capture industry profit potential stemming from conscious pet owners. The improved feeding practices can increase life expectancy of pets, resulting in higher customer lifetime value for pet food companies. Lastly, this study contributes to the pet food economics and management literature and highlights potential areas for future research to explore related to pet obesity management and pet owner practice.

The remainder of the paper is organized into five sections. Section 2 presents previous literature in pet food and obesity management. Section 3 introduces the conceptual and empirical framework, as well as the data. Quantitative results are presented in section four. Further discussion of the results and marketing implications to improve competitive advantage is also

discussed in section four. Section 5 presents conclusions, limitations, and potential directions for further research.

3.2 Literature Review

3.2.1 Pet Obesity Literature

The current body of literature has examined several aspects of obesity in pets, including factors contributing to obesity (Courcier et al. 2010; Crane 1991; Forrest et al. 2021; Yaguiyan-Colliard et al. 2006), direct and indirect costs of obesity (Bomberg et al. 2017; Chandler 2018; Chen et al. 2020; Stookey et al. 2020), and parallels between obesity in children and pets (Bartges et al. 2017; Downes et al. 2014; 2015; Muñoz-Prieto et al. 2018). This literature provides evidence to support mirroring causes of obesity in pets and humans, whereas the level of obesity is determined by the ratio of calories consumed and calories expended on a daily basis (Muñoz-Prieto et al. 2018). However, pet obesity determinants have been found to align closer with obesity in children instead of obesity in adults, as the nutritional, dietary, and activity decisions in children and pets are largely under the control of the parent/pet owner instead of the child or pet themselves (Pretlow and Corbee 2016; Tvarijonaviciute, Muñoz-Prieto, and Martinez-Subiela 2020).

Factors credited to cause obesity in dogs have been classified into three broad categories: genetic pre-disposition, reproductive management and dietary/exercise (human influenced) management to control the ratio of calories ingested and calories expended (Bland et al. 2019). Genetic predisposition consists of the inherited characteristics of the individual dog such as dog type (breed), size, age, and sex, whereas obesity has been found to be higher in female dogs, older dogs, and smaller dog breeds (Usui et al., 2016). Reproductive management (the owners'

decision to spay or neuter the pet or allow the pet to remain intact) also correlates with the animal's sex. Obesity has been found to be higher among spayed (female dog) or neutered (male dog) pets than those who are intact (Bjørnvad et al., 2019; Muñoz-Prieto et al., 2018). More specifically, spayed female dogs are more likely to be obese than any other dog, followed by neutered male, intact female, and intact male. The growing obesity trend in several companion animal breeds indicates a disproportionate calorie balance, most likely resulting from overfeeding, insufficient exercise, or both (Bartges et al. 2017; Chandler 2018; Crane 1991). The findings of these studies highlight the significance of human management practices in controlling obesity levels in pets.

3.2.2 Previous Pet Obesity Modeling Studies

There is a common theme among previous pet obesity studies to utilize logistic regression methods to evaluate obesity factors among pets. Several studies have documented the use of univariate and multivariate logistic regression modelling to assess pet obesity (Avsar, Ham, and Tannous 2017; Pegram et al. 2021; Suarez et al. 2022). Yet, multivariate analysis has been widely used in studies assessing pet obesity allowing researchers to assess the impacts of multiple factors. For instance, Colliard et al. (2006) confirmed that genetic pre-disposition factors such as dog age, gender, neutering status, and breed are significant determinants of pet obesity. Likewise, Courcier et al. (2010) found that owner socioeconomic factors such as age and income are positively correlated with the obesity of pets.

Although the findings of previous pet obesity studies have several advantages, there is a significant limitation in documenting body weight due to its inconsistency (Downes et al., 2014; Pegram et al., 2021; White et al., 2011). Specifically, differences between overweight and

obesity perceptions of pet owners and veterinarians' assessments can lead to potential inconsistencies in estimation results. While it is common to estimate and compare the results of multiple econometric models to prevent false positive results (Type 1 error), the current methods of capturing quantitative pet obesity data have the potential to reduce a study's power (Pegram et al., 2021). To interpret findings correctly, it is recommended to consider the entirety of the statistical results and not rely solely on statistical significance (Leek & Peng, 2015; Pegram et al., 2021). Doing so results in higher economic significance and impact of the findings.

3.2.3 Measuring Pet Obesity

Body condition score (BCS) is the most commonly used method for analyzing pet obesity. Multiple animal studies have utilized BCS to measure obesity levels and identify characteristics for different classes of obesity (Clingerman & Summers, 2012; Leleu & Cotrel, 2006; Maurya et al., 2009; Speakman et al., 2003). This approach provides a subjective and inexpensive method for assessing the body fat of the animal to indicate the presence of excessive body fat (Clingerman & Summers, 2012). Previous studies have identified common characteristics among different obesity classes through discussion with doctors and the synergies of excess body fat measurement such as body mass index (BMI) and human practices. However, there is a significant difference between this approach in human and pet studies. Humans have the ability to verbally discuss and self-report all practices/characteristics over a period that contribute to their obesity levels, whereas the reported pet practices/characteristics are only observable by pet owners. Although this approach is available, there are only a limited number of studies that take this approach to identify the human management characteristics by pet owners that contribute to obesity in pets. Furthermore, current literature has not examined the

effect of dog behavior to human management practices to identify the impact this has on dog obesity levels.

This study examines human and dog characteristics to identify common management practices among pet owners of obese and non-obese dogs. The findings of this study expands the literature regarding how to measure and analyze common characteristics across pet obesity classes. Methods can be generalized and used in other industries that have similar obesity measures and observable characteristics.

3.3 Methods & Data

3.3.1 Conceptual Framework

There are several factors that contributes to obesity in pets, yet obesity is directly determined by the animal's genetic predisposition, reproductive management, and the ratio of caloric intake to caloric output (Crane 1991; German 2006; Robertson 2003). Caloric intake and caloric output are factors related to the energy ingested through food and expelled through exercise, which are directly under the control of the pet owner. For instance, caloric intake refers to the number of calories ingested by a pet daily, determined by the feeding habits of the pet owner. These habits include food amount, feeding frequency, and the type of food provided to the pet. Caloric output refers to the physical activity experienced by the dog which burns the ingested calories, and is directly related to exercise time, exercise frequency, exercise type, which can under the control of the pet owner. Following a similar approach found in previous literature, we begin by modelling the body condition as a function of caloric intake, caloric output, and genetic pre-disposition factors. However, we incorporate human management factors (i.e., owner perception of the dog's body condition) as a determinant of caloric input and caloric

output factors. The owner's perception of the dog affects the level of caloric input and output provided (i.e., owner feeds underweight dog more, or increase exercise level of a dog that is perceived to be overweight). Therefore, we define dog body condition as:

(1) *Dog Body condition = f (caloric input (HMF), caloric output (HMF), genetic pre-disposition)*

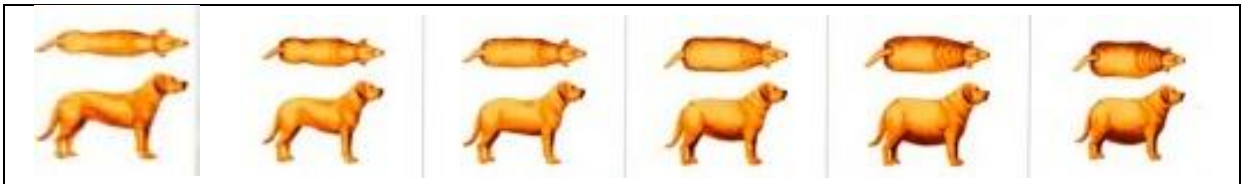
The proposed framework above helps to model dog obesity to identify the effects of factors associated with genetic pre-disposition, caloric intake, and caloric output on obesity in dogs with other human management (non-caloric input-based) analyzed as control variables. This study places special emphasis on the factors related to caloric input, as they are more relevant for pet food industry decision makers. More specifically, we examine factors such as feeding amount, feed type, and feeding frequency. The analysis is conducted using pet owner and dog characteristic data to reflect the association of current pet owner management practices and the level of obesity within their dogs.

3.3.2 Data Collection

We analyze dog body condition and feeding management behavior of dog owners subscribed to Whole Dog Journal; a leading dog care, feeding, and training journal. This audience is used because it uniquely offers access to "health-conscious" pet owners who would be the likely targeted audience of health/weight management product designs. We define a health-conscious pet owner as an owner who plays a particular emphasis on the pet's health/nutrition, weight, or digestion (Payne 2021). Additionally, the Whole Dog journal audience is selected due to ease of access to a large population of 19,399 dog owners who subscribe to the journal.

A structured Qualtrics survey is administered to capture primary cross-sectional data. The questionnaire includes 31 multiple choice, open-ended, and Likert scale questions classified into six sections. In the first section, we collected pet owner's demographic characteristics such as gender, age, household annual income, and level of education. Section two collects information regarding the dog's genetic pre-disposition and body condition, including: dogs per household, dog sex, reproductive status, breed, age, weight, perceived body condition score, and where the dog spends their time during the day (i.e., majority inside, majority outside, etc.). To provide accuracy among responses, pet owners with multiple dogs are asked to select one dog as a reference for survey responses. For uniformity among the dog selection process, pet owners are asked to refer to the dog with the name closest to the beginning of the alphabet (e.g., if the dogs' names are Aaron and Donald, the survey should be completed in reference to Aaron). Perceived body condition scores are provided as a score based on the pictures shown below in Figure 3.2, in which owners are asked to indicate the picture that best reflects the current condition of the dog.

Figure 3.2. Dog Body Condition Score



1	2	3	4	5	6

Sections 3 and 4 include questions associated with the dog's caloric intake type and amount. Information regarding the dog's primary food (excluding treats) are collected in section

three. This information includes food type (wet, dry, etc.), daily feeding frequency (how often the dog is fed), food amount (how much is fed in one sitting), and brand/product information (company, brand, and formulation). Section 3 also includes a question to identify the pet owner's concern for obesity for their dog. Section 4 requests information on the treats provided to pets, such as treat type, treat frequency, treat amount, and adjustment of primary food based on treats given. Treat brand/product information is also collected.

Section 5 included observational behavior questions that aim to determine how well pet owners understand their dogs and how the dog can influence owners and the food they are given. Specific questions included: behavior of the dog while waiting for food/treats, attitudes of the animal when offered food/treats, the attitude of the animal when the owner is eating, frequency that pet owners give food to the dogs when at dinner table, and attitude of the pet owner towards the dog when s/he is gazing/whining while s/he is eating.

Lastly, the final section included questions aimed at understanding the physical activity and caloric output levels. Weekly exercise frequency and duration is collected for low, medium, and high intensity exercises. We examine weekly exercise information to account for variation between exercise amount and type during the workweek and weekend. For instance, may be likely that employed pet owners provide different exercise regiments during the workweek, as opposed to the weekend due to time restrictions. Low intensity exercise refers to any exercise that requires minimal energy (e.g., taking a dog for a walk). Medium exercise refers to any type of exercise that require a short burst of energy (e.g., playing fetch or other organized activity). High intensity exercise includes exercises that requires a high energy level for longer periods of time (e.g., running or jogging). Examples of each exercise type are provided to respondents to clarify distinctions between each, as shown in Appendix A.

3.3.3 Data Summary

There are 5,970 total respondents to the survey, of which only 1,173 responses are considered usable: representing a response rate of 20% of the response sample, and 6% of total Whole Dog Journal subscribers. This is because not all survey respondents provided answers to all questions. We define a "usable response" as one from someone who feeds their dog a commercial dog food diet (wet or dry) and can answer all questions related to caloric intake, caloric output, and genetic pre-disposition. Examining pet owners who feed their dogs a commercial dog food diet enables us to examine the nutritional information of the diet, including product calories, suggested serving size, and macronutrients. We are unable to obtain this information from pet owners who feed home-cooked/prepared diets.

Of the usable responses, 89% are female dog owners, 10.5% are male dog owners, with 0.5% preferring not to specify their gender. This trend is consistent with previous studies that also reported more female than male dog owners (Murray et al., 2010; White et al., 2016). Additionally, previous studies found that dog owners are generally less than 55 years old. In our study, more than 82% of respondents are above the age of 56 years old. While this age distribution is reflective of the Whole Dog Journal population, it only partially represents the pet owner population. Specifically, our study only include 2.56% of millennial respondents (between the ages of 25-40), yet millennials are the largest share of pet owners in the United States (37%), followed by baby-boomers (27%) (Statista 2021a; Wall 2022). Therefore, our study provides information on baby boomer dog owners but does not fully reflect the millennial dog owner population.

In terms of income, the usable responses showed reasonable variability across income ranges. Only 1% of respondents earned less than $20,000 annually, 25% earned between $20,000 and $59,999, 30% earned between $60,000 and $99,999, and 44% earned $100,000 or more. This income breakdown is similar to the income demographic breakdown of dog owners reported in a 2022 report by Package Facts. According to this report, 47% of their sample earned more than $100,000 annually, and 40% of owners had an annual household income of $50,000 to $99,000 (Sprinkle 2022).

The respondents reported comparable sex preconditions of their dogs. Half of the sample consisted of male dogs, while the other half are female dogs. A majority of the respondents (85%) had their dogs fixed (neutered or spayed), with males accounting for 43% and females accounting for 45% of the dogs that are fixed. The perceived body condition scores showed low response variability. Slightly more than half of the dogs (51%) had a BCS of (1), 40% had a BCS of (2), and 8% had a BCS of (3). Only 1% of the respondents reported a BCS of (4), and less than 1% reported a BCS of (5). None of the dog owners in the usable sample reported a BCS of (6). Although the variability of body condition scores is low, this is not surprising given that the population of inference includes vested/health-conscious dog owners who subscribe to a health, care, and training journal (Whole Dog Journal). These owners likely prioritize their dogs' health and well-being, which could lead to them being more attentive to their dogs' weight and body condition.

There is variability in the descriptive statistics of the caloric intake variables. Many dog owners (approximately 94%) feed their dogs dry kibble as their primary food type, while only a small percentage (6%) provide wet food. When it comes to feeding frequency, most dogs are fed twice per day (about 80% of owners), with a small percentage of dogs being fed once, three, or

four times a day. A small fraction of respondents (1%) reported providing their dogs constant access to food. Regarding treats, only a very small percentage of dog owners never feed their dogs treats, while a larger percentage (14%) feed treats only on special occasions. Many dog owners give their dogs treats once or twice per day (22% and 22%, respectively), and a significant proportion feed their dogs treats three or four times per day (12% and 6%, respectively). Finally, a surprising number of dog owners (24%) provide their dogs with treats five or more times per day. When it comes to treat types, most dog owners feed their dogs crunchy treats (67%) and soft/moist treats (42%). A smaller percentage provide jerky treats (15%), dental treats (32%), animal part treats (17%), rawhide treats (3%), or table scrap treats (18%). It is worth noting that many respondents fed their dogs multiple treat types, so the percentages do not sum to 100%.

3.3.4 Empirical Model

The body condition score (BCS) is the primary variable of interest and is modeled as the dependent variable in our analysis. Both qualitative and quantitative explanatory variables are examined as independent variables to identify individual marginal effects on BCS levels within the dogs. Therefore, we estimate body condition as:

(3.1)

$$BCS_i = \alpha_0 + \beta_i\, total\_cal + \gamma_{1i}\, lexc\_freq + \gamma_{2i}\, lexc\_dur + \gamma_{3i}\, mexc\_freq + \gamma_{4i}\, mexc\_dur + \gamma_{5i}\, hexc\_freq + \gamma_{6i}\, hexc\_dur + \rho_{1iz}\, breed + \rho_{2i}\, dog\_intact + \rho_{3i}\, dog\_sex + \rho_{4i}\, dog\_age + \varepsilon_i$$

where for observation i, α represents the intercept, β indicates the parameter estimate for the total calorie/caloric intake variables, γ indicates the caloric output parameter estimates, ρ represents the genetic pre-disposition variable parameter estimates, and ε represents the unobserved variation in the body condition score. Specific variable descriptions and characteristics are provided below in Table 3.1.

Table 3.1. Empirical Model Variable Description

Variable	Variable Name	Description	Min.	Max.	Mean	Std. Dev.	Obs. (n)
total_cal	**Total Calories (per week)**	Amount of calories given to dog per week (Food calories per day + treat calories per day)	40.5	8,798	7023.9	5741.4	1,173
feed_freq	**Primary Food frequency (per day)**	Number of times per day dog is fed primary food (1= once, 2= twice, 3= three times, 4= free feed or constant access to food)	1	4	2.13	0.62	1,173
feed_type	**Primary Food type**	Type of primary food given to dog (0=dry, 1=wet)	0.06			0.25	
treat_freq	**Treat frequency (per day)**	Number of times per day dog is given treat (0= never, 0= only on special occasions, 1= once a day, 2= twice a day, 3= three times a day, 4= four times a day, 5= 5 or more times a day)	0	5	2.44	1.76	

Table 3.1. Empirical Model Variable Description (cont.)

Variable	Variable Name	Description	Min.	Max.	Mean	Std. Dev.	Obs. (n)
treat_cal_percent	**Treat Calorie Percentage**	Percentage of total calories derived from treat calories. (treat calories / total calories) * 100	0	20	2.52	2.77	1,173
fbw	**Feeding based on weight**	Amount of food calories given to dog per day (food frequency * food amount * food calories)	31.9	8568	863.04	763.3	1,173
fbv	**Feeding based on vet recommendation**	Amount of treat calories given to dog per day (treat frequency * treat amount * treat calories)	0	3003	140.2	332.7	1,173
low_exc_freq	**Low intensity exercise frequency**	Number of times per week dog participates in low intensity exercise activity	0	35	9.38	7.05	1,173
low_exc_dur	**Low intensity exercise time**	Duration of low intensity exercise activity (in minutes)	0	180	29.75	22.20	1,173
med_exc_freq	**Medium intensity exercise frequency**	Number of times per week dog participates in medium intensity exercise activity	0	35	5.72	5.49	1,173
med_exc_dur	**Medium intensity exercise time**	Duration of medium intensity exercise activity (in minutes)	0	90	15.39	15.27	1,173

Table 3.1. Empirical Model Variable Description (cont.)

Variable	Variable Name	Description	Min.	Max.	Mean	Std. Dev.	Obs. (n)
hi_exc_freq	**High intensity exercise frequency**	Number of times per week dog participates in high intensity exercise activity	0	35	3.44	4.86	1,173
hi_exc_dur	**High intensity exercise time**	Duration of high intensity exercise activity (in minutes)	0	180	13.42	23.23	1,173
breed	**Dog Breed**	Size of the dog based on dog breed (1= Toy breed, 2= Small breed, 3= Medium breed, 4= Large breed, 5= Giant breed)	1	5	3.09	1.02	1,173
dog_age	**Dog age**	Age of dog (in months)	3	214	78.53	48.41	1,173
dog_sex	**Dog sex**	0= male, 1=female	0	1	0.50	0.50	1,173
dog_intact	**Dog intact**	Dog's reproductive status 0=spayed/neutered, 1=intact	0	1	0.13	0.33	1,173

In addition to assessing the effect of total calories on body condition, we also attempt to identify the relationship between specific feeding management practices and the pet's body condition score. More specifically, we incorporate the feeding frequency and treat frequency variables to isolate the effect of the oftenest of feed from what is fed (e.g., total calories). This provides further insight to assess if higher body condition is correlated among higher feeding frequency or treat frequency. We also have interest in identifying the breakdown of total calories

provided from feed versus that of treats. Therefore, we develop a treat calorie percentage variable which signifies the portion of calories derived from treats. To calculate this variable, we divided the amount of treat calories by the combined total calories. We assess this variable as a percentage to normalize the effect of treat calories, while preventing possible multi-collinearity with total calories.

We incorporate interaction terms to control for interactors between explanatory variables on total calories. More specifically, we first interact total calories per week with the binary feed based on weight variable. Because the dependent variable is the weight of the animal, it is possible that pet owner who feed based on weight alter the number of total calories based on the weight of the animal. Therefore, we isolate this combined effect to owners who feed based on weight and the number of calories they feed. Likewise, we create an interaction effect for pet owners who feed based on the recommendation of veterinarian as the veterinarian likely provides feeding recommendations based on the current body condition of the animal. Thus, we create a binary variable for feeding based on veterinarian recommendation. Lastly, we incorporate an interaction effect for the breed size and total calories to control for the difference in feeding calories based on the size of the animal. It is likely that larger dogs are provided more calories than smaller dogs, etc. Emphasis is placed on caloric intake variables (i.e., total calories, feeding frequency and feeding amount) to achieve the study objectives and develop implications based on the empirical findings. Thus, after incorporating the interaction terms, the empirical model is estimated as:

(3.2)

$$BCS_i = \alpha_i + \beta_{1i}\ total\_cal + + \beta_{2i}\ fbw + \beta_{3i}\ total\_cal * fbw + \beta_{4i}\ fbv + \beta_{5i}\ total\_cal * fbv + \beta_{6iz}\ total\_cal * breed + \beta_{7iz}\ feed\_freq + \beta_{8iz}\ feed\_type + \beta_{9iz}\ treat\_freq$$

$$+ \beta_{10iz}\,\text{treat\_cal\_percent} + \gamma_{1i}\,\text{lexc\_freq} + \gamma_{2i}\,\text{lexc\_dur} + \gamma_{3i}\,\text{mexc\_freq}$$

$$+ \gamma_{4i}\,\text{mexc\_dur} + \gamma_{5i}\,\text{hexc\_freq} + \gamma_{6i}\,\text{hexc\_dur} + \rho_{1iz}\,\text{breed}$$

$$+ \rho_{2i}\,\text{sex\_repro} + \rho_{3i}\,\text{dog\_sex} + \rho_{4i}\,\text{dog\_age} + \varepsilon_i$$

Combining the impact of the total calorie interaction terms, we can express the model in the more compact form below.

(3.3)

$$\text{BCS}_i = \alpha_i + \text{total\_cal}\,(\beta_{1i} + \beta_{3i}\,\text{fbw} + \beta_{5i}\,\text{fbv} + \beta_{6iz}\,\text{breed}) + \beta_{2i}\,\text{fbw} + \beta_{4i}\,\text{fbv}$$

$$+ \beta_{7iz}\,\text{feed\_freq} + \beta_{8iz}\,\text{feed\_type} + \beta_{9iz}\,\text{treat\_freq} + \beta_{10iz}\,\text{treat\_cal\_percent}$$

$$+ \gamma_{1i}\,\text{lexc\_freq} + \gamma_{2i}\,\text{lexc\_dur} + \gamma_{3i}\,\text{mexc\_freq} + \gamma_{4i}\,\text{mexc\_dur}$$

$$+ \gamma_{5i}\,\text{hexc\_freq} + \gamma_{6i}\,\text{hexc\_dur} + \rho_{1iz}\,\text{breed} + \rho_{2i}\,\text{sex\_repro}$$

$$+ \rho_{3i}\,\text{dog\_sex} + \rho_{4i}\,\text{dog\_age} + \varepsilon_i$$

3.3.5 Estimation Approach

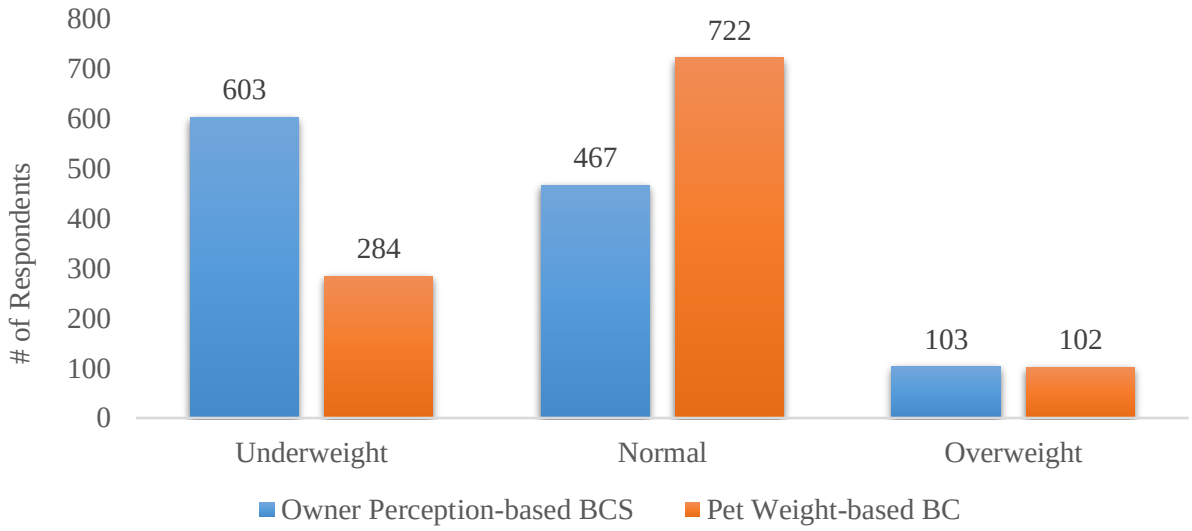
To estimate the effects of pet owner feeding management practices on body condition, we define an ordered Probit model with the owner perceived body condition score as the dependent variable. The reported body condition scores are classified into three weight categories to account for the low variability of the body condition score. The categories are underweight (BCS=1), normal weight (BCS=2), and overweight (BCS=3, 4, 5). We also notice high skewness of the reported body condition data, as a majority of the body condition scores are underweight. There is literature to document that pet owners are likely to underrate their dog's body condition score by one category in comparison to a vet's recommendation (Eastland-Jones et al., 2014). To test and account for the underreporting, we develop a weight-based body condition where we

utilize the reported weight of the dog and the normal weight range of each dog breed size based on the American Kennel Club (American Kennel Club, 2022). Therefore, the dog is classified as underweight if the reported weight is below the recommended weight range, normal weight if the reported weight is within the weight range and overweight if the reported weight is above the recommended weight range. An example of normal weight ranges by breed size, and classification based on actual weights are reported Table 3.2 below. Figure 3.3 shows the distribution of body condition scores (BCS) for owner-perception-based BCS and pet weight-based BCS. The pet weight-based BCS displays a normal distribution, whereas the owner-perception-based BCS is skewed towards underweight BCS ranking. This potentially indicates the presence of underreporting of dog body condition by pet owners.

Table 3.2. Body Condition Category Classification by Breed Size

Breed Category	Normal Weight Range	Actual Weight	Body Condition Category
Toy	4 – 15 lbs.	17 lbs.	Overweight
Small	15 – 35 lbs.	27 lbs.	Normal weight
Medium	35 – 70 lbs.	28 lbs.	Underweight
Large	70 – 100 lbs.	121 lbs.	Overweight
Giant	100 – 200 lbs.	140 lbs.	Normal weight

Figure 3.3. Owner Perception-based Body Condition vs. Pet Weight-based Body Condition



An Ordered Probit regression model is used for empirical estimation due to the ordered categorical nature of the dependent BCS variable. Traditional logistic regression models do not allow for regression estimation without losing the ordering nature of the BCS variable. Instead, the ordered Probit model allows for proper estimation, while preserving the categorical ordering

of the dependent variable. In the ordered Probit model, the outcome variable ranges from 1-3 where probability estimates of being in a particular BCS category are defined as:

(3.4)

$$P(BCS = 1|x) = P(BCS^* \leq \alpha_1|x) = P(x\beta + \varepsilon \leq \alpha_1|x) = \varphi(\alpha_1 - x\beta)$$

$$P(BCS = 2|x) = P(\alpha_1 < BCS^* < \alpha_2|x) = \varphi(\alpha_2 - x\beta) - \varphi(\alpha_1 - x\beta)$$

$$P(BCS = 3|x) = P(BCS^* > \alpha_3|x) = 1 - \varphi(\alpha_3 - x\beta)$$

when *BCS*=1 if $BCS^* \leq \alpha_1$; BCS =2 if $\alpha_1 < BCS^* < \alpha_2$; BCS =3 if $BCS^* \geq \alpha_3$

While the categorical BCS provides useful insights on a dog's body condition, it has limitations in terms of the variability and explanatory power. This is due to the restricted nature of the dependent variable, which can only have a value of 1, 2, or 3. To overcome this limitation, we generated a weight deviation variable that has a continuous nature. To explain this further, we created an average weight for each dog breed size category by computing the mean of the normal weight range. We then subtracted the mean weight from the actual weight of the dog. This resulted in a continuous weight deviation variable, the signs of which indicate whether the dog is overweight (positive), underweight (negative), or at a normal weight (weight deviation equals zero). Although this method provides valuable insight into the number of pounds by which the dog's actual weight differs from the mean weight for the breed size category, we acknowledge that the magnitude of the weight deviation varies for each breed size. For example, being two pounds overweight for a toy breed dog is more concerning than a giant dog that is two pounds overweight. To account for this, we normalized the weight deviation model by dividing the weight deviation by the mean of the breed category. This approach takes into consideration the magnitude difference and provides a more accurate estimation of a dog's weight deviation.

To test for robustness and differences between the perception-based and weight-based body condition, we estimate the ordered Probit model for both categorical dependent variables. In addition, we estimate an ordinary least square regression model using the weight deviation variable as the dependent variable. All results are presented and reported in the results section to follow. We also conduct a robustness check for the continuous weight deviation model through estimation of the model for each breed size. The results of the individual breed size models (reported in Appendix C) closely resemble the findings of the original continuous weight deviation model.

3.4 Results

Results from the Ordered Probit and OLS regressions are shown in Table 3.3. The measures reported in Table 3.3 for the weight deviation are the marginal effects, as the coefficients reported in an OLS estimation reflect the marginal effects. The marginal effects for the two Ordered Probit regression models are reported below in 3.4. We examine and discuss the reported marginal effects of the statistically significant parameter estimates. The primary estimates of interest include all feeding management variables related to caloric intake (e.g., total calories, feed type, feed frequency, treat frequency, treat calorie percentage, feed based on weight, and feed based on vet recommendations). The interaction terms for total calories are also examined and compared among the three models. It is worthwhile noting that marginal effects of the total calorie variable alone, and the interaction parameters, were significantly smaller than the other estimates. This is due to the marginal effects assessing the impact of a change in one calorie on the outcome variable. For practical purposes, the reported parameter estimates (Table

3.3) and marginal effects (Table 3.4) for the total calorie variable and calories interaction terms have been scaled reflect a 100-calorie change, instead of a one-calorie change.

There are apparent differences between the sign and statistical significance of the perception-based model parameter estimates when compared to the weight-based Ordered Probit and weight deviation models. The statistically significant parameter estimates of the caloric intake variables are similar for the three models. However, the total calories and small breed interaction term is reported as perception-based categorical model, the total calories parameter estimate is negative, whereas the weight-deviation model reports a positive parameter estimate. In addition, the parameter estimate for the dog intact variable is negative in the perception-based categorical model, whereas the weight-based categorical model reports a positive parameter estimate. We cannot confirm which model has the most accurate parameter estimate results as the parameter estimate of the third model (i.e., weight-based categorical model for the calories and small breed interaction term, and the weight deviation model for the dog intact parameter estimate) is not statistically significant. However, based the parameter estimate results the weight-based categorical model and the weight deviation model had a higher number of common statistically significant parameter estimates (i.e., parameter estimates were statistically significant in both models), whereas the perception-based categorical model reported only two parameter estimates that were statistically significant in the other two models (two common parameters with the weight-based categorical model, and two that were common with the weight deviation model). Additionally, signs of the categorical model marginal effects reported in Table 3.4 are similar to the reported parameter estimates shown in Table 3.3. Additionally, the two categorical models reported similar signs for all statistically significant marginal effects except for the total calories and dog intact variables. The differences in the perception-based categorical model

findings are believed to be the result of pet owners underreporting the body condition score. Many of the dogs in the perception-based model are classified as underweight but moved to normal weight in the weight-based model, potentially indicating bias within the perception-based model. Some of that bias might be reflected in the results of the perception-based model indicating a higher calorie intake of dogs perceived to be underweight while they are in the normal or overweight category based on the actual weight.

Table 3.3 Ordered Probit and OLS Parameter Estimates

	Ordered Probit estimation		OLS estimation
Variable	**Perception-based**	**Weight-based**	**weight deviation**
Caloric Intake Parameter Estimates			
total calories	0.0004 (0.000)	**0.003*** (0.000)	**0.001***** (0.000)
feed frequency	-0.057 (0.061)	**-0.173***** (0.065)	**-0.097***** (0.030)
feed type	-0.128 (0.149)	**-0.614***** (0.150)	-0.041 (0.096)
treat frequency	-0.003 (0.022)	0.022 (0.022)	0.002 (0.008)
treat calorie percentage	0.112 (0.216)	-0.353 (0.215)	**-0.174**** (0.071)
feeding based on weight (fbw)	-0.023 (0.156)	0.206 (0.143)	**0.073*** (0.043)
feeding based on vet recommendation (fbv)	**0.542***** (0.191)	0.121 (0.195)	0.106 (0.095)
total calories * fbw	-0.0001 (0.000)	-0.002 (0.000)	**-0.0007*** (0.000)
total calories * fbv	-0.0011 (0.000)	0.002 (0.000)	0.0003 (0.000)
total calories * toy breed	0.0015 (0.000)	0.003 (0.000)	0.006 (0.000)
total calories * small breed	**-0.005***** (0.000)	0.003 (0.000)	**0.003***** (0.000)
total calories * medium breed	0.0002 (0.000)	0.002 (0.000)	0.0005 (0.000)
total calories * giant breed	**-0.008**** (0.000)	-0.0003 (0.000)	-0.0001 (0.000)

Table 3.3 Ordered Probit and OLS Parameter Estimates (cont.)

Variable	Ordered Probit estimation		OLS estimation
	Perception-based	**Weight-based**	**weight deviation**
Caloric Output Parameter Estimates			
low exercise	-0.0006 (0.017)	0.0003 (0.000)	**0.0013*** (0.000)
medium exercise	**-0.0070**** (0.030)	0.001 (0.000)	0.0002 (0.000)
high exercise	**-0.0077**** (0.036)	-0.005 (0.000)	0.0005 (0.000)
Genetic Pre-disposition Parameter Estimates			
toy breed	0.086 (0.220)	**1.786***** (0.210)	**0.441***** (0.168)
small breed	**0.503**** (0.162)	**0.901***** (0.184)	0.012 (0.052)
medium breed	-0.112 (0.160)	**0.817***** (0.166)	**0.120***** (0.034)
giant breed	**0.963**** (0.297)	0.564 (0.268)	-0.053 (0.071)
dog intact	**-0.218*** (0.116)	**0.265**** (0.131)	-0.004 (0.056)
dog sex	-0.0416 (0.071)	**-0.426***** (0.076)	**-0.119***** (0.021)
dog age (months)	**0.002***** (0.001)	0.001 (0.000)	**0.0006**** (0.000)
constant			**-0.107****
cut 1	0.0024	-0.2315	---
cut 2	1.4226	2.1083	---
Observations	1,173	1,108	1,168
R-squared	---	---	0.2315
Root MSE	---	---	0.3826
Pseudo R-squared	0.0555	0.1451	---

*Note: ***** $p < 0.01$; ****** $p < 0.05$; * $p < 0.10$*

Table 3.4 Ordered Probit Marginal Effects

	Perception-based			Weight-based		
Variable	**P(BCS=1)**	**P(BCS=2)**	**P(BCS=3)**	**P(BCS=1)**	**P(BCS=2)**	**P(BCS=3)**
Caloric Intake Marginal Effects						
total calories	**0.0005***	-0.0002	**-0.0003****	**-0.0008*****	0.0002	**0.0006*****
	(0.0003)	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)
feed frequency	0.021	-0.013	-0.008	**0.047*****	**-0.023****	**-0.024*****
	(0.233)	(0.014)	(0.009)	(0.018)	(0.009)	(0.009)
feed type	0.048	-0.029	-0.019	**0.168*****	**-0.081*****	**-0.087*****
	(0.053)	(0.032)	(0.021)	(0.042)	(0.022)	(0.023)
treat frequency	0.001	-0.0007	-0.0004	-0.006	0.003	0.003
	(0.008)	(0.005)	(0.003)	(0.006)	(0.003)	(0.003)
treat calorie percentage	-0.042	0.025	0.017	0.096	-0.045	-0.050
	(0.079)	(0.047)	(0.031)	(0.062)	(0.030)	(0.032)
feeding based on weight (fbw)	0.033	-0.021	-0.012	-0.026	0.013	0.013
	(0.032)	(0.019)	(0.013)	(0.025)	(0.013)	(0.013)
feeding based on vet rec. (fbv)	**-0.174*****	**0.088*****	**0.085*****	**-0.059****	**0.024****	**0.035***
	(0.039)	(0.018)	(0.024)	(0.030)	(0.011)	(0.020)
Caloric Output Marginal Effects						
low exercise	0.0003	-0.00001	-0.000009	-0.000007	0.00003	0.00004
	(0.00006)	(0.00003)	(0.00002)	(0.00004)	(0.00002)	(0.00002)
medium exercise	**0.0003****	**-0.0002****	**-0.0001****	-0.00004	0.00002	0.00002
	(0.0001)	(0.00007)	(0.00005)	(0.00009)	(0.00004)	(0.00005)
high exercise	**0.0003****	**-0.0002****	**-0.0001****	0.0001	-0.00006	-0.00006
	(0.0001)	(0.00008)	(0.00005)	(0.00009)	(0.00004)	(0.00005)

Table 3.4 Ordered Probit Model Marginal Effects (cont.)

	Perception-based			Weight-based		
Variable	**P(BCS=1)**	**P(BCS=2)**	**P(BCS=3)**	**P(BCS=1)**	**P(BCS=2)**	**P(BCS=3)**
Genetic Pre-disposition Marginal Effects						
toy breed	-0.074	0.043	0.031	**-0.437*** **	0.060	**0.377*** **
	(0.072)	(0.038)	(0.035)	(0.026)	(0.066)	(0.071)
small breed	-0.060	0.028	**0.032***	**-0.334*** **	**0.200*** **	**0.134*** **
	(0.041)	(0.025)	(0.017)	(0.030)	(0.025)	(0.025)
medium breed	0.038	-0.025	-0.013	**-0.302*** **	**0.203*** **	**0.010*** **
	(0.032)	(0.021)	(0.011)	(0.028)	(0.024)	(0.013)
giant breed	**-0.160****	**0.061*** **	**0.098***	**-0.192****	**0.155*** **	0.037
	(0.073)	(0.023)	(0.059)	(0.077)	(0.055)	(0.023)
dog intact	**0.081***	**-0.049***	**-0.032***	**-0.072****	**0.035****	**0.037****
	(0.043)	(0.026)	(0.017)	(0.036)	(0.018)	(0.019)
dog sex	0.015	-0.009	-0.006	**0.116*** **	**-0.056*** **	**-0.060*** **
	(0.026)	(0.016)	(0.010)	(0.020)	(0.011)	(0.011)
dog age (months)	**-0.0009*** **	**0.0005*** **	**0.0004*** **	-0.0004	0.0002	0.0002
	(0.0003)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)

*Note: ***** p < 0.01; ****** p < 0.05; * p < 0.10*

3.4.1 Caloric Intake Results

3.4.1.1 Total Calories and Body Condition

The parameter estimate for the total calorie per week variable is statically significant and positive in the weight-based categorical model and the weight deviation model, yet there are statistically significant marginal effects in each of the three models. The weight deviation marginal effects suggest that a 100 calorie increase in the dog's diet results in a 0.001 increase in the weight deviation. Similarly, the marginal effects in the weight-base categorical model

suggest that an increase in total calories is associated with higher probability of the dog being in the overweight category (BCS=3) by 0.06%. In contrast, the marginal effects in the perception-based body condition model suggest that an increase in the total calories provided is associated with a higher likelihood of the dog being classified as underweight (BCS=1) by 0.05% and lower the likelihood of the dog being overweight (BCS=3) by 0.03%.

The parameter estimates of the total calories and feeding based on weight (fbw) interaction term is statistically significant in the weight deviation model only. Interpreting the marginal effect suggest that an increase in the total calories provided to dogs who are fed based on weight reduces the weight deviation by 0.007. The total calories and small breed interaction parameter estimate suggest that an increase in the total calories provided to small breed dogs increases the weight deviation of the dog by 0.003. Conversely, the parameter estimates in the perception-based categorical model suggest a negative correlation between total calories provided to small breed dogs and the perceived dog body condition.

3.4.1.2 Food Type and Body Condition

Food type is found to be negatively correlated with body condition score in the weight-based categorical model. More specifically, the weight-based model parameter estimate for food type suggest that pet owners who fed wet dog food are more likely to have an underweight dog. The marginal effects for the food type variable suggest that feeding wet food as the primary dog food type is associated with higher probability of the dog being in the underweight category by 16.8% and reduced likelihood of the dog being normal weight or overweight by 8.1% and 8.7% respectively. The findings go against previous literature as wet food is found to be more prevalent among overweight pets. The findings of this study are suspected to be due to the

breakdown of pet owners who feed wet food (6%) versus dry food (94%). It is also possible that the amount of food feed per serving varies amongst pet owners who feed a wet food versus dry food diet. More specifically, it has been documented that dogs have a stronger like for wet food than dry food because wet food is more flavorful to the dog. As a result, the dog possibly eats more of the wet food at one time than the dry food due to a stronger desire for wet food, as would be like a human who eats more cake than vegetables due to the flavor desire in a cake.

3.4.1.3 Feeding Frequency and Body Condition

The data reveals a surprising finding that there is a negative statistical relationship between feeding frequency and a dog's body condition. This suggests that pet owners who feed more often are likely to own a dog with a lower weight deviation. There are two possible causes to explain this finding. First, there is potential endogeneity as a result of simultaneity bias from potential correlation between the feeding frequency and the dog's body condition score. More specifically, the owner potentially determines the feeding amount based on the dog's body condition. For example, an owner may feed an underweight dog more frequently to increase the dog's weight, while an owner of an overweight dog may feed less frequently to lower the dog's body condition. Although we attempt to control for this possibility using binary *feed based on weight* and *feed based on veterinarian recommendation* variables, it is likely that this is still present as the *feed based on weight* parameter estimate is not statistically significant.

The second potential cause of the negative feeding frequency parameter estimate is that there is an actual negative relationship between body condition and feeding frequency. For instance, there is research in human food/weight-management suggesting that eating smaller meals more frequently can potentially aid in weight loss (Smeets and Westerterp-Plantenga

2008; Ma et al. 2003). Yet, there is a need for more research to confirm the robustness of these findings (Paoli et al. 2019; Schoenfeld, Aragon, and Krieger 2015). Nonetheless, this pattern is likely to be true for pets in this study, as it is possible that pet owners who feed their pets more frequently also give them smaller portions or lower calorie diets. This could be an unintentional consequence of feeding their pets more frequently. Thus, we examine the relationship deeper in Figures 3.4, 3.5, 3.6, and 3.7 which report the breakdown of calories per serving, and amount per feeding among the different feeding frequency levels. Figure 3.4 reports the average feed amount per serving for each body condition category based on the feeding frequency. There are three key trends shown in Figure 3.4. First, overweight dogs are fed more cups per serving on average, potentially signaling that reverse causality is not the cause of the negative feeding frequency parameter estimate. Second, dog owners who feed four times per day reported the highest average feeding amount for all body condition categories. This is likely due to the small number of respondents (6%) who feed their dog four times per day. Third, there is a downward trend between the feeding frequencies (excluding four times per day) for all body condition categories, likely suggesting that the portion sizes decline as the feeding frequency increases. Although the negative relationship between feeding amount and feeding frequency may be true for the sample as a whole, we examine the robustness of the downward trend by examining feed amount and feeding frequency based on breed size.

Figure 3.4. Average Feed Amount per Serving by Feeding Frequency for Body Condition

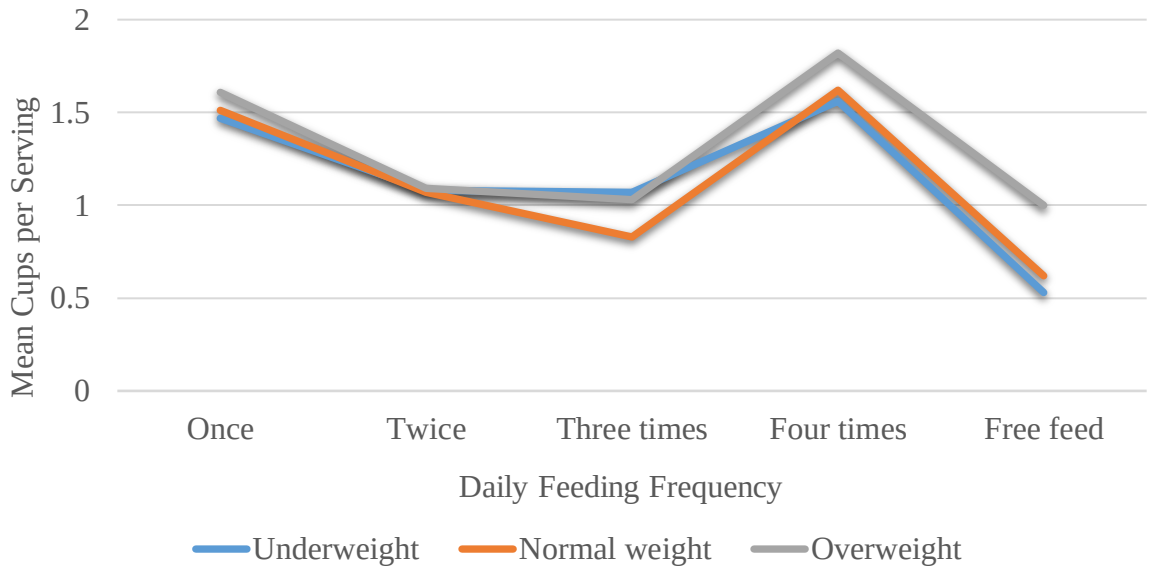
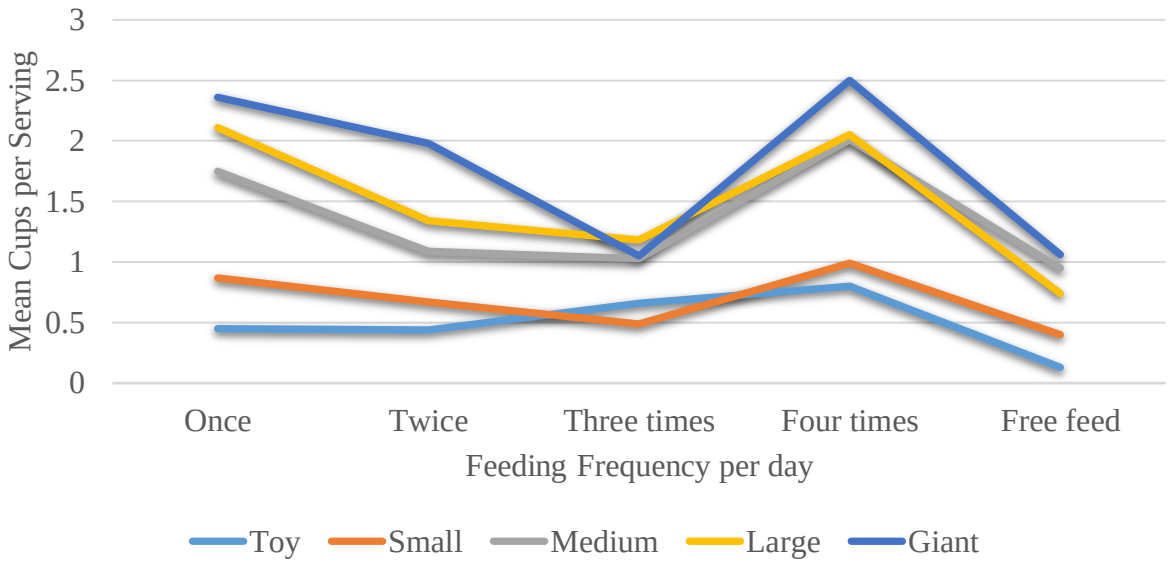


Figure 3.5 presents the average food amount per serving for each dog breed size based on the feeding frequency per day. Similar to Figure 3.4 the average feeding amount is highest among dogs that are fed four times per day for all dog breed sizes. In addition, owners of giant dogs provided the highest feed amount among per serving among all dog breed sizes, as expected. Lastly, we see a similar downward trend between mean cups per serving and feeding frequency for all dog breeds except the toy breed. This potentially aligns with the findings in Figure 3.4 that feeding amount decreases as feeding frequency increases. However, further research is needed to fully understand the complex relationship between feeding frequency and feed amount.

Figure 3.5. Average Feed Amount per Serving by Feeding Frequency for Dog Breed Size



We examine Figure 3.6 and Figure 3.7 to identify if pet owners who feed more frequently provided lower calorie diets on average. Figure 3.6 presents the average calories per serving of each body condition category based on the feeding frequency per day, which highlights three key points. First, the mean calories per serving increases between feeding frequencies of 1-3 times per day for underweight dog owners. However, the uptrend reverses into a downward trend for dog owners who feed four times per day and those who free feed. Second, free feed has the highest calories per serving amount among the owners of overweight dogs. Lastly, there is a downward trend for overweight dog owners ranging from those who feed once per day to those who feed four times per day. This potentially signals that owners of overweight dogs who feed more frequently provide lower calorie diets, yet more research is needed to confirm this hypothesis. To check the robustness of the downtrend in mean feeding amount, we examine Figure 3.7.

Figure 3.6. Feed Calories per Serving by Feeding Frequency for Body Condition Category

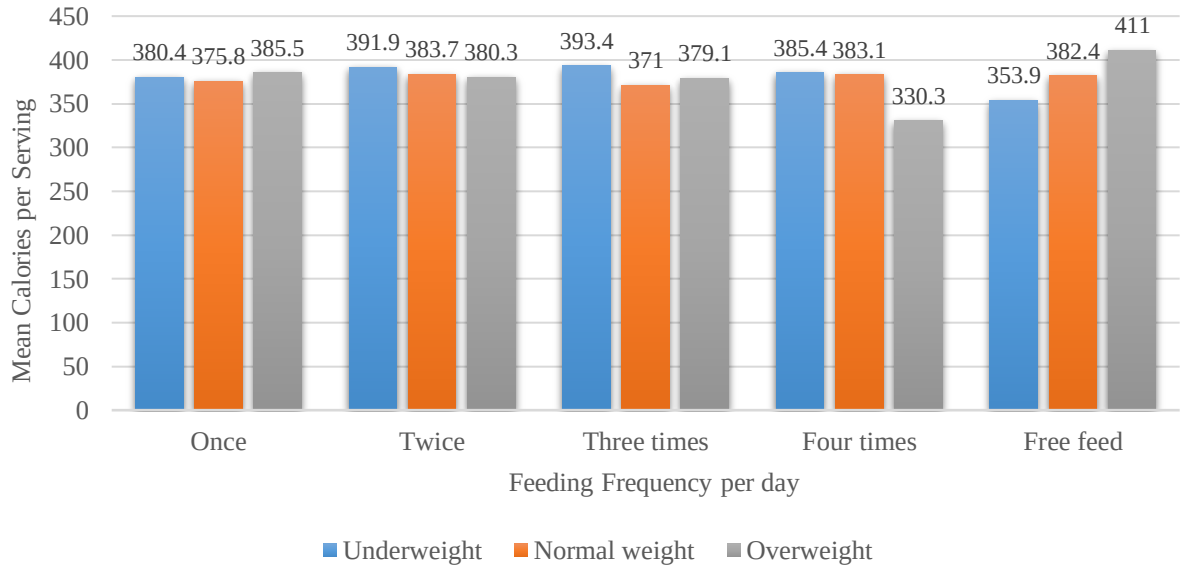


Figure 3.7. Feed Calories per Serving by Feeding Frequency for Dog Breed Sizes

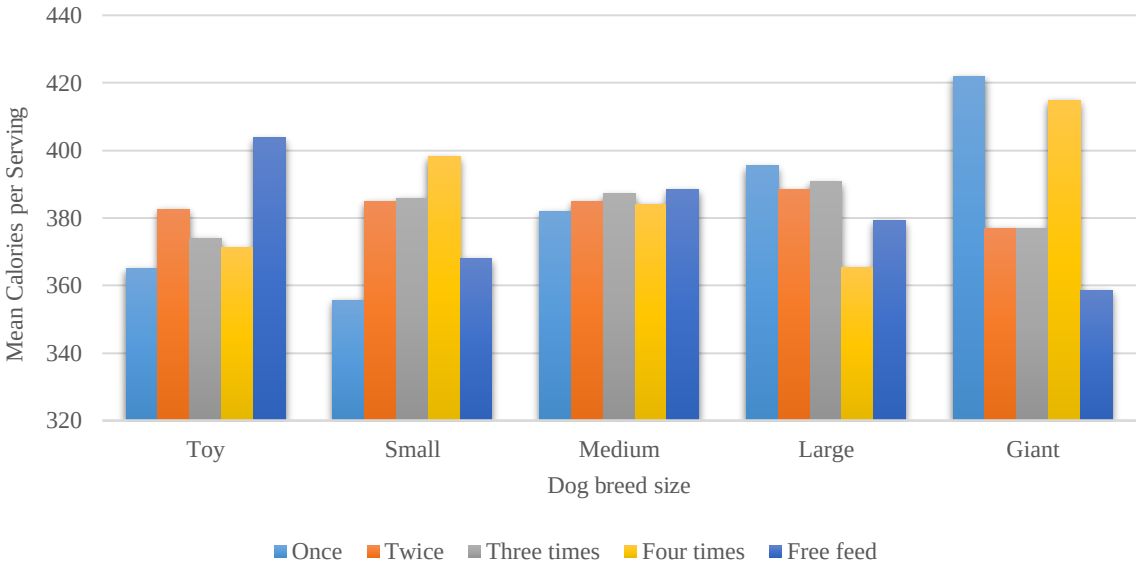


Figure 3.7 displays the average feed calories per serving of each dog breed size based on the feeding frequency per day. We notice that free feed has the highest amount of calories per serving between the toy and medium dog breed owners. Additionally, Figure 3.7 shows an

uptrend among the feeding frequencies per day for small dog breeds. Regarding the large and giant dog owners, there is a downward trend of mean calories per day among the feeding frequencies, excluding those who feed four times per day. The trends in Figure 3.7 potentially signals that owners of large and giant dogs provide higher calories per serving on average when providing lower feeding frequencies; whereas toy, small, and medium dog owners provide lower calories per serving on average as the feeding frequency increases. Overall, Figures 3.4, 3.5, 3.6, and 3.7 provides additional context about the negative feeding frequency parameter estimate, however, future research is needed to confirm this hypothesis statistically and robustly.

3.4.1.4 Impact of Feeding based on Owner Perception and Veterinarian Recommendation

It is also found that how a pet owner determines the feeding amount is correlated with the body condition of the dog. Both feed based on weight and feed based on vet recommendation is positively correlated with higher body condition. Specifically, the feed based on weight parameter estimate in the weight deviation model signals that the dog's weight deviation increases by 0.073 when the owner determines the feeding amount based on the weight of the dog. Similarly, the marginal effects of the perception-based and weight-based categorical models indicates that owners who feed based on the recommendation of the veterinarian are correlated with reduced probability of the dog being classified as underweight (BCS=1) and increased likelihood of the dog being in the normal (BCS=2) and overweight (BCS=3) categories. However, there is a difference in the magnitudes of the effects in the two models as the perception-based model indicates that feeding based on vet recommendation is associated with higher probability of the dog being normal weight (8.8%) than overweight (8.5%). Yet, the marginal effects in the weight-based model indicates owners who feed based on vet

recommendation is associated with higher likelihood of the dog being overweight (3.5%) than normal weight (2.4%).

3.4.2 Caloric Output Results

After analyzing the caloric output-related variables, the combination of the three models suggests that exercise plays an important role in maintaining a healthy body condition for dogs, as expected. The results revealed that medium and high intensity exercise activities are more common for underweight to normal dogs. Specifically, the parameter estimate for the weight-deviation model indicates that increasing the dog's level of low intensity exercise likely increases the dog's weight deviation by 0.0013. The marginal effects of the perception-based categorical model indicate that increasing the amount of medium intensity exercise is associated with increased probability of the dog being classified as underweight by 0.03% and reduced probability of the dog being normal weight or overweight by 0.02% and 0.01% respectively. Likewise, the high-intensity exercise marginal effect in the perception-based model indicates that increasing the dog's level of high intensity exercise is associated with increased likelihood of the dog being underweight by 0.03% and reduced likelihood of being normal- and over-weight by 0.02 and 0.01% respectively.

3.4.3 Genetic Pre-disposition Results

3.4.3.1 Dog Breed and Body Condition

Examining the genetic pre-disposition parameter estimates, we notice that parameter estimates for the toy and medium dog breeds variables are statistically significant and positive. Therefore, the Weight Deviation model results suggest that toy and medium dog breeds are

associated with higher weight deviation than larger dog breeds, as expected. In the weight-based categorical model, toy breed dogs are associated with reduced probability of being underweight by 43.7%, whereas the associated likelihood of being overweight increases by 37.7%. When examining the marginal effects of the perception-based model, a small dog breed is associated with increased probability of being overweight (BCS=3) by 3.2%. For medium sized dog breeds, is associated with reduced probability of being underweight by 30.2%, and increased likelihood of being normal weight or overweight by 20.3% and 10% respectively. The likelihood of a dog in the giant breed category being underweight (BCS=1) is associated with a reduction by 16% in the perception-based model and associated with higher probability of being normal weight or overweight by 6.1% and 9.8% respectively. Conversely, the probability of a giant breed dog being underweight is associated with a reduction by 19.2% and associated with an increase the probability of being normal weight by 15.5%.

3.4.3.2 Dog Sex/Reproductive Status and Body Condition

The findings related to genetic pre-disposition variables are noteworthy. Specifically, the dog sex and dog intact variables had positive coefficients and marginal effects, although previous literature suggested a negative expected coefficient for both variables. The results for the dog-intact parameter estimates are also mixed. The perception-based model suggested that intact dogs are associated with higher probability of being underweight, while the weight-based model suggested the opposite. The findings of the perception-based model are more consistent with previous studies, as dogs who have been fixed (spayed or neutered) tend to be more overweight (Bjørnvad et al., 2019). Regarding dog sex, the weight deviation parameter estimate indicates that female dogs are associated with a 0.119 lower weight deviation than that of male dogs.

Likewise, the marginal effects of the dog sex variable in the weight-based categorical model indicates that female dogs are associated with an 11.6% higher probability of being underweight, and reduced probability of being normal weight and overweight by 5.6% and 6% respectively. These findings contradict previous literature that suggests female dogs tend to be more overweight (Usui et al., 2016). However, the findings in this study are likely due to the dependent variable being weight-based instead of categorical body condition as utilized in previous studies. Based on previous findings, male dogs are likely to have higher weight than female dogs. However, we did not normalize the weight-based body condition classification by dog sex (i.e., the same weight ranges were used for female dogs as male dogs). Therefore, future research should utilize normal weight ranges of the dog breeds that are classified by dog sex to enhance the estimation findings.

3.5 Discussion

The findings suggest potential opportunities exist for pet food companies to capture profit potential and increase their market competitiveness through pet food product innovation and differentiation strategies aimed at healthy weight management in dogs. Higher food calorie diets are found to be correlated with increased likelihood of a dog being classified as overweight and obesity, thus suggesting potential opportunities for low-calorie product designs. However, given the growth in the health and wellness product offerings, pet food companies should identify ways to establish uniqueness within their low-calorie product innovations. The study also found that an increase in total calories is associated with a greater impact on small dog breeds, providing potential evidence that smaller dog breeds are more likely to be overweight or obese compared to larger dog breeds as an additional pound of weight has a greater impact on them. Hence, opportunity exist for pet food companies to focus more on caloric intake for smaller dogs

through smaller portion sizes or developing low-calorie products specifically designed for small breeds.

There also exists a potential opportunity for pet food companies to increase their competitiveness through product offerings and designs for specific body-conditions. The results indicate that feeding based on weight is more common among owners with higher body conditions. However, the results of the total calories and feeding based on weight potentially signals that pet owners who feed based on weight are associated with providing lower product calories to higher weight deviation (overweight / obese) dogs, and higher calorie amounts to lower weight deviation (underweight) dogs. There is potential for pet food companies to tailor product calories and portion sizes for different dog body conditions (e.g., offer food for underweight, normal weight, or overweight) to assist pet owners in determining the optimal amount of calories to provide their pet. However, further research is needed to confirm if the general dog owner population who determine feeding amounts by weight follows similar calorie trends.

It is important to remember that the findings are based on results of Whole Dog Journal subscribers. The study sample can be potentially representative of other customers in the "health conscious" niche market but may not be reflective of the general U.S. pet owner population. Further, pet food companies can potentially utilize the findings to assist in product design, innovation, and marketing to target "conscious" pet owners in the U.S. However, further research is needed to examine the purchasing habits and perceptions of "conscious" pet owners to increase the ability of pet food companies align product offerings with the demands of conscious pet owners and increase their ability to compete effectively in the health and wellness market.

3.6 Conclusion

As the pet food industry continues to grow, with rising sales and increasing pet ownership, concerns over obesity are also on the rise. This presents a unique opportunity for pet food companies to capture the profit potential of the growing health and wealth management product market. To do so, pet food companies must have a clear understanding of the feeding management factors of pet owners and how their products can help address these issues through product development, design, and marketing strategies. Therefore, this paper aims to identify the most common owner feeding management factors among underweight, normal weight, and overweight dogs, to determine which feeding factors contribute most to overweight dogs. We examine factors such as feed type, feed frequency, feed-to-treat ratio, and total calorie intake. By identifying these factors, pet food companies can develop products that cater to the specific needs and preferences of pet owners, ultimately leading to healthier and happier pets.

The research findings suggest that feeding management parameter estimates have a comparable impact across all three models. However, the sign of the total calorie marginal effects differs between the perception-based model and the two weight models. The perception-based model suggests a negative correlation between the total calories consumed and the dog's body condition, which could be due to the underreporting of the body condition score by pet owners. The data also reveal a surprising negative correlation between the frequency of feeding and a dog's body condition. This may be because pets who eat more frequently have increased medium and high exercise levels. Other factors such as portion size and calorie content may also play a significant role in a dog's body condition. Therefore, it is essential to understand the

relationship between feeding frequency and a dog's body condition to ensure that pets are fed appropriately and maintain a healthy weight.

The study findings the two weight-based models are more similar than those of the perception-based model. More specifically, we suspect a potential presence of underreporting in the perception-based model, potentially suggesting that the weight-based models may be more reliable in determining the impact of feeding management on animal weight and body condition. It is important to note that weight-based models may not be practical or feasible in all situations. In such cases, perception-based models may be necessary to use when weight measurements are not available or difficult to obtain. Overall, these results shed light on the impact of feeding management on animal weight and body condition, highlighting the significance of accurate data collection and analysis in animal nutrition research.

This study has some limitations that need to be considered. Firstly, while the data is useful in providing access to health-conscious customers, it has low variability in the body condition score. The sample of pet owners in this study has a higher focus on the health and weight management of their pets. As a result, there was low variation in the reported body conditions of the dogs as majority of the dogs in the sample were underweight or normal weight, which could have reduced the predicted impact of the factors related to obesity. In addition, there Secondly, there is a potential for underreporting of perceived body condition scores by the pet owners. The weight-based generated body condition helps to address this to some extent, but more accurate reporting of the body condition is still needed.

There are various opportunities for future research to improve the current study's limitations and expand the modeling approach to gain a better understanding of the owner management factors contributing to pet obesity. Specifically, further research could explore the

impact of specific diets and portion sizes on pet body condition and determine if they contribute to the negative correlation between feeding frequency and body condition. Additionally, this study brings to light the significance of accurately reporting the body condition score by pet owners to ensure that feeding management parameter estimates are properly estimated. Future research should aim to identify and implement ways to improve the accuracy of identifying the body condition of pets. Lastly, to gain a more comprehensive understanding, additional explanatory variables such as pet food prices, presence of product attributes, and ingredient alternatives should be assessed to determine their potential impact on pet body conditions.

Chapter 4 - An Assessment of Pet Food Demand Structure and the Existence of Pre-Committed Demand

4.1 Introduction

4.1.1 Background and Problem Statement

The pet food industry has undergone significant changes in customer demand and sales over the past decade as global sales increased by 72%, from $59.3 billion in 2010 to $102 billion in 2020 (Statista 2021a). Changes in pet food demand levels have been accredited to increased pet ownership, higher disposable income, changing customer preference for higher priced premium products, and more health conscious customers (Passport, 2019; Statista, 2021a). Synergies derived from these demand shifting factors have led to rising demand for specialized dietary products, offering increased nutritional value to pets (Waters 2021; Statista 2021b; Wagoner et al. 2022). The change in pet food demand has been accompanied by a rise in demand for high protein products. The type of proteins demanded have been animal-based proteins (ABP) with chicken and beef being the highest demanded protein sources due to the protein richness, and low cost (Montegiove et al., 2021). There has also been a recent push towards plant-based proteins through insect, vegan, or vegetarian product trends for health and nutritional benefits. Yet, animal-based proteins have been the predominantly demanded protein sources in pet food (Aldrich 2006a; Hill 2022; Deng et al. 2016).

With over 55% of US households owning a pet, there is a growing concern for pet obesity due to a significant increase in the number of overweight and obese pets. This is problematic for dogs, as 56% of dog in the U.S. are classified as overweight or obese (American Pet Products Association, 2021). Growing pet obesity indicates a calorie imbalance, likely

caused by high calorie diets, overfeeding, and/or insufficient exercise (Chandler, 2018). While research on pet obesity has increased recently, many questions remain regarding the role of pet food marketing, product designs, and policy development to diminish pet obesity (Coy et al., 2021).

Although high protein diets have been found to facilitate weight loss in obese dogs (German et al. 2010; Blanchard et al. 2004), there is limited research to confirm the contributions of various protein sources to the rise in pet obesity concerns. However, there is research highlighting the differences in nutritional pros and cons of each protein source in human food. Animal-based proteins (ABP) such as chicken and fish are low in fat but are known to pose allergy issues for pets (Putman et al. 2017; Aldrich 2006a; Waisundara and Shiomi 2017). Beef and turkey are high in protein and pose less allergen problems but have been found to be higher in fat (Acuff et al. 2021; Vogelnest and Cheng 2013). Fish and lamb have high protein content, low in fat, but are more costly than the other common proteins like chicken or beef (Aldrich 2006b; Morin, Gorman, and Lambrakis 2021). Overall, there is a need to further understand the demand for ABP in pet food and explore if the rise in ABP helps or hurts rising obesity levels.

Often, specialized products are marketed at higher prices, in which customers in packaged food markets often exhibit a negative relationship between quantity demanded and price (as price increases, quantity demanded decreases). However, this is not always the case in pet food. For example, there was an increase in pet food prices from 2019-2021 due to supply chain disruptions, yet pet food consumption levels increased during this period (Waters 2021; Packaged Facts 2021). Conversely, rising inflation and a 14% rise in year-over-year (YOY) pet food prices in September 2022 have resulted in a decrease in the volume of pet food purchased, while pet food sales continue to rise (Gibbons 2023; Phillips-Donaldson 2023). It is in this light

that proper understanding of pet food demand and price sensitivity can be useful to industry stakeholders and policy makers enabling them to make better-informed policy and operational decisions.

Despite growing demand and changing customer preferences in the pet food industry, there is a limited number of peer reviewed studies examining pet food demand in general, and the demand for ABP. The consensus of the existing literature is that pet food expenditure is inelastic (Ehlert 1997; Henderson 2013; Schwarz, Troyer, and Walker 2007; Wolf, Lloyd, and Black 2008). However, there are potential limitations with the Consumer Expenditure Survey data utilized in previous pet food demand studies as they do not account for external factors that also explain heterogeneity of pet food expenditure levels (e.g., number of pets in a household, distinguishing from pet food expenditure and treat expenditure, and product characteristics), and their analysis to report pet food prices. Therefore, insights from these studies are beneficial, yet there is a need to identify if the current demand of pet food follows a similar trend. In addition, these insights do not consider potential pre-commitment demand levels within current pet food purchases. Pre-committed demand refers to the portion of demand that customers are willing to purchase regardless of external economic factors (i.e., price) (Tonsor and Marsh, 2007).

It has been documented that the absence of pre-commitment demand levels in empirical estimation can potentially lead to bias, inaccurate representation of pet food preferences and purchasing patterns, and overstatement of elasticity estimates (Hovhannisyan and Shanoyan 2019).

4.1.2 Research Objectives

This study aims to estimate the pet food demand structure accounting for potential pre-commitment levels in 46 US markets. The findings will help to address the current gap in pet food literature and shed light on customer preferences for animal-based proteins in dog food. Specific objectives include:

(1) To estimate consumer's potential pre-committed and discretionary demand for five categories of dog food based on the type of animal-based protein (ABP).

(2) To present and discuss the implications for stakeholders in the pet food industry.

To achieve the research objectives, this study empirically evaluates pet food demand by exploiting recent advances in the consumer demand literature. The conceptual design of this paper draws insights from consumer demand theory and existing pet food demand studies to understand the interactions of price and other purchasing factors on pet food demand (Ehlert 1997; Henderson 2013; Schwarz, Troyer, and Walker 2007). A generalized Exact Affine Stone Index (GEASI) model that includes potential pre-committed demand quantities into the consumer demand structure is employed.

This study will contribute to the literature in three important ways. First, it expands the existing literature on pet food demand and elasticities, providing a modernized understanding of the pet food demand structure and how customers respond to price changes. Secondly, the study will utilize the Circana panel dataset, which offers detailed information on U.S. pet owners and pet food characteristics. This is beneficial because previous pet food demand literature has been limited in its ability to inform pet food decision makers due to the lack of comprehensive household and purchasing data. For example, previous studies have relied on data from the Consumer Expenditure Survey (CES), which only provides information on pet food spending per

household but not on specific product types and attributes purchased. By utilizing the Circana panel dataset, this study will provide a comprehensive analysis of elasticities based on specific product and market characteristics. Lastly, the study will contribute to the existing literature on pre-committed demand using the GEASI modeling approach.

This paper is divided into five sections. In section two, we present the findings of previous literary studies on animal-based proteins in pet food, as well as pet food demand. In section three, we define our methods and data. Section 4 presents the results of the empirical estimation. Further discussion of the estimation results will be presented in section five. Lastly, section six includes the conclusion, implications, and future research directions.

4.2 Literature Review

4.2.1 Health Benefits of Animal-Based Protein Use in Pet Food

While there are many sources of protein available, animal-based proteins are the most common in dog food, including chicken, beef, lamb, pork, and fish. Each of these proteins has its own nutritional profile, which can affect the overall quality of dog food. Although there are some studies documenting the nutritional pros and cons of the common animal-based proteins (e.g., chicken, beef, and turkey) for use in pet food, we glean from studies in literature about livestock and human health to identify the nutritional benefits of other non-common animal-based proteins found in pet food. The findings of these studies are summarized and discussed below.

The common animal-based proteins derived from livestock are beef, lamb, and pork. Each of these sources are high in protein content and provide a good source of essential amino acids (Acuff et al. 2021). However, they all have been found to be high in fat content, which can

be linked to higher levels of obesity in pets, and more specifically dogs. Similarly, lamb and pork are good alternatives for dogs with allergies or sensitive stomachs, but this is not the case for beef. For instance, beef is a common allergen for dogs, making it less suitable for dogs with food sensitivities (Vogelnest and Cheng 2013; Raditic, Remillard, and Tater 2011).

Poultry (also marketed as fowls), including chicken, turkey, and duck, is a common animal-based protein source used in both wet and dry dog food. Chicken, in particular, is the most widely used and demanded animal-based protein source, offering high protein and low-fat health benefits, and is rich in essential amino acids that aid in muscle development (Putman et al. 2017; Aldrich 2006a). However, it is also a common allergen for dogs, making it less suitable for many dog breeds with food sensitivities. Turkey also provides a lean source of protein that is low in fat and calories, high in essential amino acids, a good source of vitamin B6, and promotes relaxation and reduces stress in dogs (Aldrich 2006a). However, it poses potential issues related to digestion and gastrointestinal problems, as well as allergen issues. Duck is yet another lean source of protein that is low in fat and calories, a good source of essential amino acids, and promotes blood cell health (Deng et al. 2016). Duck is a good alternative for dogs with chicken or beef allergies. However, due to its lower supply, it is usually more expensive and difficult to procure.

Fish protein is a popular ingredient in many dog foods in which salmon is the most commonly used type of fish. Salmon is a great source of essential amino acids and high levels of omega-3 fatty acids, providing numerous health benefits for a dog's immune system, coat, and skin. Additionally, salmon is high in vitamin D, which supports bone health (Montegiove et al., 2020). Salmon is also a great option for dogs with food sensitivities or allergies. However, salmon can be high in fat, which can lead to obesity in dogs. Salmon often contains high levels

of mercury, which can be harmful in large amounts (Waisundara and Shiomi 2017). Additionally, salmon can be more expensive compared to other commonly used proteins such as chicken and beef. Other aquaculture options, such as shrimp, tuna, and trout, are also excellent sources of lean protein, rich in antioxidants and high in omega-3 fatty acids (Ravić et al., 2022). However, they can also be high in fat and/or cholesterol (Stoeckel et al., 2013), which can be problematic for food-sensitive dogs, and they can be relatively expensive.

When it comes to pet food, there are options for protein sources that come from wildlife or exotic animals, such as buffalo/bison, rabbit, and venison. These animal-based proteins are often a lean source of protein that is low in fat and calories (Vecchiato et al. 2022; Devadason, Anjaneyulu, and Babji 2010). However, the main issue with these proteins is their cost, as they are generally more expensive than more common sources like chicken or beef due to their lower level of supply. Additionally, the lower-fat content of these animals may pose problems for dogs that require higher levels of fat in their diets. It should also be noted that many dogs might find these protein sources less palatable than more common sources, making it less appealing for them to eat.

When considering animal-based proteins in dog food, each type has its pros and cons. Some offer high protein content and essential amino acids while being less expensive, but they are also high in allergens and fat content. Other sources offer low fat and calories; however, they tend to be more expensive. The best protein source for a dog depends on its individual nutritional needs and potential food sensitivities.

4.2.2 Previous Pet Food Demand

The current literature on pet food demand is limited in the number of conducted studies and available insights regarding the structure of pet food demand. Ehlert's (1997) log-linear elasticity analysis found that pet food and other pet-related variables (such as pet services, veterinary services, and pet supplies) were income inelastic and are not affected by seasonal trends. Schwarz (2007) investigated pet ownership and expenditure among single and married households and discovered that households with more children spent less on pets. Married women were found to exhibit less income elasticity for pet expenditure than men. Wolf (2008) observed that pet-related and veterinary expenses were more likely to increase with income, education, and family size for households that are white, married, homeowners, and living in rural areas. Henderson (2013) discovered that pet food expenses were more inelastic among married couples without children, as their pet food expenses remained unchanged during the 2008 recession. While these studies provide a foundation for modeling pet food demand, we found that these are the only available literature on this topic, resulting in limited information about pet food demand and evolving pet food customer preferences.

There are potential limitations with the data used in previous studies on pet food demand, including limited access to current demand data. In each of the existing studies, the Consumer Expenditure Survey was used to report pet food expenditure over households. However, this survey does not account for external factors that may explain heterogeneity of pet food expenditure levels, such as the number of pets in a household, distinguishing pet food expenditure from treat expenditure, and product characteristics. The data used in these surveys also fails to report pet food prices. Therefore, while insights from these studies are beneficial, there is a need to identify whether the current demand for pet food follows a similar trend.

4.3 Methods

4.3.1 Conceptual Framework

In the analysis, we examine the category-level expenditures that are distributed among different animal-based protein (ABP) categories. In addition, we examine the potential presence of pre-committed demand within dog food ABP demand as identifying pre-commitment demand helps to properly estimate the demand structure for dog food (Hovhannisyan and Gould 2011; Hovhannisyan and Shanoyan 2019; Tonsor and Marsh 2007). Over the pre-committed portion of demand, goods are treated as non-discretionary with inelastic price elasticity (Rowland, Mjelde, and Dharmasena 2017). More specifically, the pre-committed demand is insensitive to income and price changes until the pre-committed quantity levels are reached. After pre-commitment levels are achieved, discretionary (supernumerary) demand is initiated and the consumer becomes responsive to price and income changes (Rowland, Mjelde, and Dharmasena 2017). Therefore, we utilize the GEASI demand system to model pet owner decision-making. The GEASI model is preferred to the traditional Almost Ideal Demand Systems (AIDS) family models due to its ability to accommodate complex Engel curves and account for unobserved consumer heterogeneity (Hovhannisyan, Bastian, and Devadoss 2021; Pendakur 2009).

To conceptualize spending on dog food, we start with a cost function and derive the Hicksian demand equations using Shepard's Lemma. Following Pendakur (2009), Hovhannisyan and Shanoyan (2019), and Rahman et al. (2023), we consider the following log cost function implicit in the EASI demand system:

(4.1)

$$\ln C(p,u,\varepsilon) = u + \sum_{j=1}^{J} m_j(u) lnp_j + \sum_{j=1}^{J}\sum_{k=1}^{J} \alpha_{jk} \ln p_j \ln p_k + \sum_{j=1}^{J} \varepsilon_j \ln p_j$$

where C represents cost, u is utility, $\mathbf{m_j}(u)$ is a general function of u expressed as a J-vector valued function with $1'_J\mathbf{m}(u) = 1$, and $\mathbf{1}_J$ is the J-vector of ones, $\mathbf{p}_j$ indicates the product's price, α_{jk} are parameters and ε reflects the unobserved preference heterogeneity.

Applying Shephard's Lemma where $\frac{\partial lnC}{\partial lnp_i} = w_i$, and the cost function in equation 4.1, we derive a linear estimate of the EASI demand equation that satisfies consumer theory restrictions:

(4.2)

$$w_i(p,u,\varepsilon) = m_i(u) + \sum_{k=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

Following Bollino (1987), we generalize the cost function (4.1) to allow for overhead cost and incorporate pre-committed demand such that:

(4.3)

$$\ln(C - r'p) = u + \sum_{j=1}^{J} m_j(u) \ln p_j + \sum_{j=1}^{J}\sum_{k=1}^{J} \alpha_{jk} \ln p_j lnp_k + \sum_{j=1}^{J} \varepsilon_j \ln p_j,$$

where r_j is the pre-committed quantity of the *j*th product.

Next, generate the GEASI model through by applying Sheppard's Lemma to equation (4.3) and differentiating both sizes of the cost function with respect to ln p_i. Thus, the GEASI model is expressed as:

(4.4)

$$\frac{\partial \ln\,(\mathrm{C}-\mathrm{r}'\mathrm{p})}{\partial \ln p_i} = m_i(u) + \sum_{k=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i \,.$$

Simplifying the left side of equation (4.4) further yields:

(4.5)

$$\frac{\partial \ln\,(\mathrm{C}-\mathrm{r}'\mathrm{p})}{\partial \ln p_i} = \frac{\partial \ln(\mathrm{C}-\mathrm{r}'\mathrm{p})}{\partial p_i}\,\frac{\partial p_i}{\partial \ln p_i} = \left(\frac{1}{(\mathrm{C}-\mathrm{r}'\mathrm{p})}\,\frac{\partial \ln(\mathrm{C}-\mathrm{r}'\mathrm{p})}{\partial p_i}\right) p_i = \left(\frac{(\partial C/\partial p_i) - r_i}{(\mathrm{C}-\mathrm{r}'\mathrm{p})}\right) p_i \,.$$

We then substitute equation (4.5) into equation (4.4), yielding:

(4.6)

$$\left(\frac{(\partial C/\partial p_i) - r_i}{(\mathrm{C}-\mathrm{r}'\mathrm{p})}\right) p_i = m_i(u) + \sum_{k=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i \,.$$

Rearranging equation (4.6) for $\frac{\partial C}{\partial p_i}$ yields the following expression:

(4.7)

$$\frac{\partial C}{\partial p_i} = r_i + \frac{1}{p_i}\left(C - r'p\right)\left(m_i(u) + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right).$$

To generate Hicksian budget share equations, we multiply both sides of equation (4.7) by $(\frac{p_i}{C})$.

However, we understand that $w_i = \left(\frac{\partial C}{\partial p_i}\right)\left(\frac{p_i}{C}\right) = \left(\frac{q_i\, p_i}{C}\right)$, therefore the Hicksian budget share equation can be expressed as follows:

(4.8)

$$w_i = \frac{r_i p_i}{C} + \left(1 - \frac{r'p}{C}\right)\left(m_i(u) + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right).$$

Assuming the consumer is utility-maximizing, we replace C with consumer total expenditure X to obtain the implicit GEASI Marshallian demand system. We then follow Lewbel and Pendakur (2009) by replacing $m_i(u)$ with $\sum_{s=1}^{L} \beta_{is} y^s$ with $y = \ln(X - r'p) - w'\ln p$ and the real income polynomial function denoted as *S* provides a flexible depiction of Engel curves. Thus, the GEASI Marshallian demand system is expressed as:

(4.9)

$$w_i = \frac{r_i p_i}{X} + \left(1 - \frac{r'p}{X}\right)\left(\sum_{s=0}^{L} \beta_{is} \left(\ln(X - r'p) - w'\ln p\right)^s + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right) + \varepsilon_i \, .$$

Equation (4.9) is conditional on the adding up restrictions ($\sum_{i=1}^{J} \beta_{i0} = 1;\ \beta_{i0} = 0, \forall\ s = 1, \ldots, L;\ \sum_{i=1}^{J} \alpha_{ik} = 0, \forall\ k = 1, \ldots, J$) and symmetry ($\alpha_{ik} = \alpha_{ki}, \forall\ i, k = 1, \ldots, J$). Additionally, the joint restriction of $r_i = 0, \forall\ i = 1, \ldots, J$ allows for the EASI model to be nested within the specification of the GEASI model.

The variable r_i represents the pre-committed demand for the jth product that not affected by changes in price or income. Meanwhile, the term $\sum_i t_i p_i$ denotes the pre-committed expenditures. Discretionary (supernumerary) expenditures are calculated by subtracting the pre-committed expenditure from the total expenditure *X* (Hovhannisyan & Shanoyan, 2019; Zheng & Henneberry, 2009).

4.3.2 Elasticity Estimation

We derive the Hicksian, Marshallian, and expenditure elasticity formulas following the methods of Hovhannisyan and Shanoyan (2019). Thus, the GEASI expenditure elasticity is derived as follows:

(4.10)

$$\mathrm{E} = (\mathrm{diag}(\mathrm{W}))^{-1}\left[\left[I_j + \left(\left(\frac{X - r'p}{X}\right) * B\right)(\ln p)'\right]^{-1}\left[\frac{r \circ p}{X} + \frac{r'}{X} * A + B\right]\right] + 1_j\,,$$

where E represents the (Jx1) expenditure elasticity vector with e_i indicating the ith element, W denotes the (Jx1) vector of observed ABP dog food budget shares, ln p is the vector of log prices, B represents the (Jx1) vector with the *i*th element characterized as $\sum_{l=1}^{L}(\beta_{il} + \beta_{il}^{u} Urb_{rt}) ly^{l-1}$, A= $\left(\sum_{r=0}^{L}\beta_{ir}\,(\ln(X - r'p) - w'lnp)^{r} + \sum_{k=1}^{J}\alpha_{ik}\,lnp_k\right)$, 1_j is a (JxJ) vector of ones. Following Hovhannisyan and Bastian (2022), $r \circ p$ represents a Hadamard-Schur product that is used to account for possible price endogeneity derived from the presence of expenditure on both sides of the GEASI equation. More specifically, the Hadamard-Schur product is a point-wise element-wise multiplication of the matrices of pre-committed consumption and prices, where $r \circ p$ = [r_1p_1,…., r_Np_N] (Hovhannisyan & Bastian, 2022). However, Hovhannisyan and Bastian (2022) incorporated a Hausman-type price instrument, following the approaches used in Zhen et al. (2013), that is constructed based on the respective prices from the neighboring markets. Assuming that prices from the neighboring markets reflect the manufacturing, wholesaling, and retail cost of dog food; the price instruments are used to construct an empirical demand and reduced-form price equation system (Hovhannisyan & Bastian, 2022). However, we do not incorporate price instruments to utilize in this study, therefore we set $r \circ p$ = 0 for the purposes

of this study. We understand there is potential presence of price endogeneity in our estimation, resulting in biased estimation results. However, the methods and results in this study can serve as a baseline for future studies examining the demand structure of categories of animal-based dog food. We suggest that future studies incorporate the price indexes when estimating the elasticities of demand.

GEASI Hicksian elasticities are expressed as:

(4.11)

$$e_{ij}^{H} = \frac{1}{w}\left[\frac{r_i p_i}{X} - \frac{r_i p_i}{X}\, A + \left[1 - \frac{r'p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}, \forall\, i, j = 1, \ldots., J,$$

We then use the expenditure (e_i) and Hicksian (e_{ij}^{H}) elasticity estimates to derive the Marshallian price elasticity estimates (e_{ij}^{M}) from the Slutsky equation:

(4.12)

$$\left(e_{ij}^{M}\right) = e_{ij}^{H}\, \frac{\alpha_{ij}}{w_i} - w_j e_i$$

Therefore, we define the Marshallian price elasticity equation as follows:

(4.13)

$$e_{ij}^{M} = \left[\left[\frac{r_i p_i}{X} - \frac{r_i p_i}{X}\, A + \left[1 - \frac{r'p}{X}\right]\alpha_{ii}\right] + \left(w_i - \delta_{ij}\right)w_i\right]\frac{\alpha_{ij}}{w_i^2} - w_j e_i$$

The above-mentioned formulas lack clarity in terms of presenting pre-committed demand effects on different elasticities (Hovhannisyan and Shanoyan 2019). However, it is crucial to account for pre-commitment to avoid overestimating elasticities (Rowland, Mjelde, and

Dharmasena 2017). Therefore, to analyze the proposed pre-commitment and elasticity equations in relation to pet food requires panel data; we utilize information on category-level expenditures, income, price, and the quantity of pet food purchases.

4.3.3 Data

The empirical analysis is based on Circana disaggregated consumer panel data detailing household pet food consumption in the United States from 2017 to 2020. In total, the data was collected from 125,814 unique households, providing demographic information, trip details and summaries, and product information. Household demographic characteristics include household size, pre-tax income, race, children's ages, household head demographics (age, education, work hours, occupation), marital status, home ownership status, number of pets (dogs and cats), region, zip code, and residential state and country. Recorded trip details include store type (such as supermarket or pet store), purchase date, trip ID (to distinguish between multiple trips by the same household in the same day), Circana week (identifying the week number), unique product code, dollars paid for product, and units purchased (product size). Unique information on trip summaries includes chain Circana and basket total (in dollars). Product information recorded includes department (in-store location of the product), aisle, product category (dog food or cat food), product type (wet, dry, semi-moist), parent company, vendor, brand, major brand, product description (including product attributes), volume value (volume equivalences), and volume description (number of ounces). The primary variables of interest for demand analysis are household income, dollars paid for the product, and units purchased. Other household information variables, trip details, and product characteristics will be used as explanatory variables in the empirical model.

4.3.4 Identifying Animal-based Protein Products

To conduct a thorough analysis of the use of animal-based proteins in dog food product categories, we examine the product characteristics of five animal-based protein products. We began by removing all non-dog food product purchases from the data, such as cat food, dog treats, and cat treats. Next, we generated a binary indicator for each of the five categories by examining the product descriptions of each purchase. For instance, for chicken protein products, we denoted any observation with the word "chicken" in the product description as "1" and "0" otherwise. We removed any products that did not distinctly list one of the five categories in the product characteristics from our sample. Some dog food products included multiple types of animal-based proteins, such as chicken and beef, turkey, and salmon, etc. This can cause problems such as inaccurate estimation and an indication of customer behavior when conducting the demand analysis. Therefore, we generated mutually exclusive categories by removing all products with overlapping animal-based protein characteristics. After removing all non-mutually exclusive dog food observations, the final subset data included in the analysis totaled 75,936 unique households.

There are important data characteristics that must be considered when examining the results of this study. First, the analyzed data excludes products that may contain a majority of one protein (e.g., 80% chicken and 20% beef) due to the removal of non-mutually exclusive products. As a result, the findings of this study only capture the demand and price effects of pure ABP products within the five categories. The study also excludes products that do not mention ABP in the product description and includes products that may only have one ABP listed in the product description despite potentially containing other ABPs in the ingredient list. Although the

findings may not encompass the complete scope of dog food product demand due to the exclusion of some products, they provide a baseline for future studies examining dog food demand structure.

4.3.5 Generating Category Prices and Quantities

Since the Circana data did not clearly define the quantity and prices for each product category, we systematically generated this information. First, we multiplied the purchase quantity in units by the volume equivalency value to determine the total purchase volume in pounds. This conversion was necessary to ensure homogenous price and quantity comparisons as some units were sold in ounces while others were reported in pounds. Next, we divided the total dollars paid for the pet food purchase by the total purchase volume to obtain the per-unit price. We then generated price and quantity variables for each product category. To reduce the computational burden resulting from the nuisance of many separability and theoretical restrictions on the GEASI model, we aggregated the individual data of each product category to monthly market-level data of 46 retail markets (listed in Appendix E -Table 5.4) from 2017-2020. Specifically, we took the mean unit price of each category within a specific market for each month during a 4-year timeframe.

4.3.6 Generating Per Capita Income

The Circana data reports consumer-level income in six income ranges obtained through a multiple-choice question. To generate per capita income for each market, we developed a two-step approach. First, we calculated the mean of each income range and applied it to the

respective consumers. However, we faced an issue with the last income range, which was presented as "$100,000 or more." As we were unsure what the "more" meant, we decided to report an average income of $100,000 for anyone who reported income of $100,000 or above. Next, we calculated the mean per capita income for each market in each year by taking the average of the reported incomes generated in step one.

4.3.7 Data Summary

Figure 4.1 reports the average budget shares of dog food for the five animal-based protein categories. As shown below, chicken is the most widely consumed ABP as it accounts for 58.3% of the total spending of the total ABP dog food spending. Beef and lamb were the second and third commonly purchased ABP in dog food with respective budget shares totaling 17.6% and 10.8% respectively. There is likely correlation between the higher allocations of chicken and beef to the higher levels of supply availability, and lower price points of each (Aldrich 2006a; Hill 2022). In contrast, lamb has been documented as a likely substitute for dogs with allergen sensitivity to chicken and beef (Aldrich 2006a), possibly providing some explanation of the higher budget share allocation over turkey and salmon.

Despite the documented health benefits of salmon and turkey, the acceptance of these proteins as a sole ABP source in dog food is relatively low as they accounted for 7.3% and 6% respectively. The smaller budget share allocated to turkey can potentially be the result of the low supply availability for use in pet food. As documented in Hill (2022), the volume of turkeys slaughtered in the U.S. is significantly lower than that of beef, pork, and chickens. Given that pet food ABP is a by-product of human food ABP production, this implies the available supply of turkey for use in pet food is lower than that of chicken and beef (Hill, 2022). Price of salmon and

turkey can also potentially explain the lower budget share allocated to these two categories, as they are typically more expensive than the chicken and beef products (Aldrich 2006a). To test this assumption, we examine the average prices for each ABP below in Figure 4.2.

Figure 4.1. Average Budget Share of Dog Food by Animal-based Protein Source

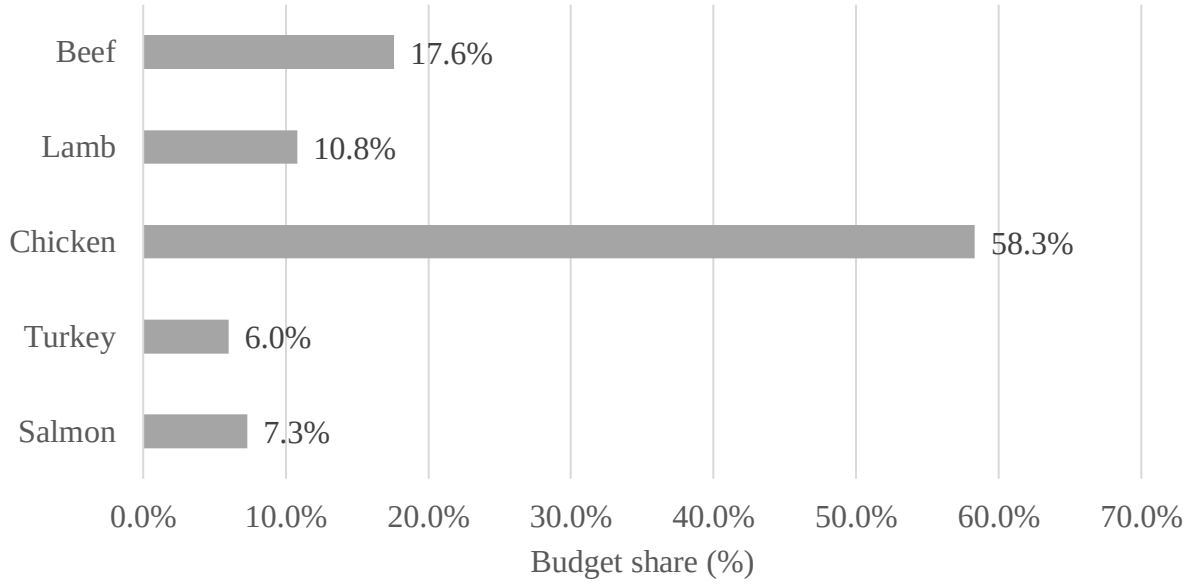


Figure 4.2. Average Dog Food by ABP Prices Across 46 US Markets over 2017-2020

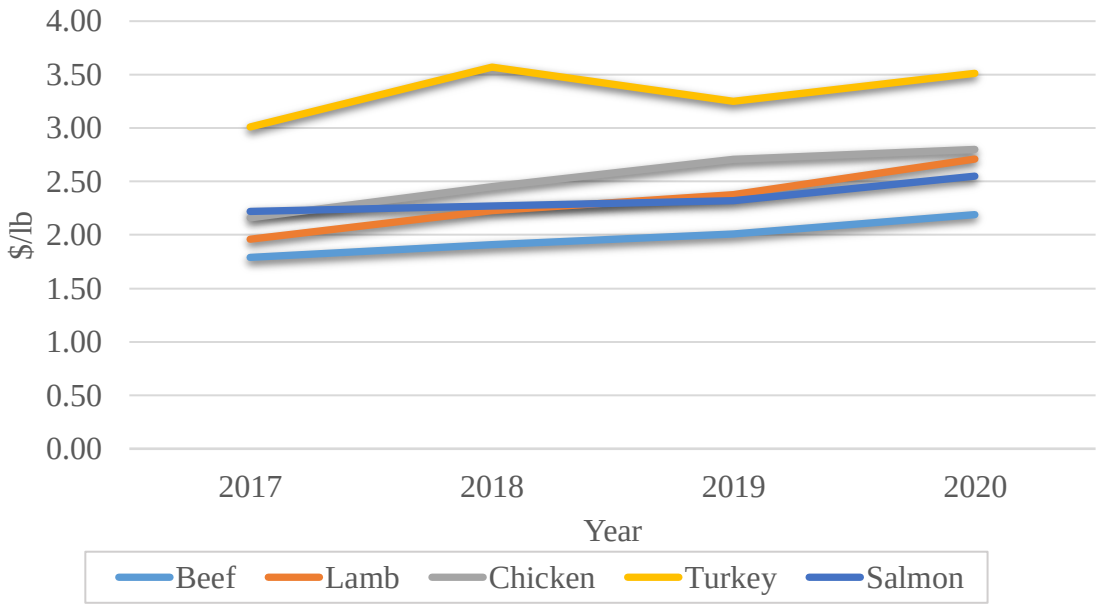


Figure 4.2 reports average dog food prices for the five ABP categories in 46 US markets from 2017-2020. As indicated below, turkey has the highest price per pound among the five categories, which provides an indication of the potential negative relationship between the price and budget share allocated to turkey. It can also be observed that the two lean products (i.e., chicken and turkey) are priced higher on average than the other three ABP that are higher in fat content (i.e., beef, lamb, and turkey). Beef is the most affordable ABP dog food option over the sample period. Surprisingly, lamb and salmon displayed lower prices on average than chicken. Further research is needed to explain the underlying reasons for the price differences. However, it is likely that the average price per pound of lamb will surpass the price of chicken if the trend lines in Figure 4.2 continue. Further, all five categories followed a similar dynamic over the sample period, displaying a trend of rising prices from 2017 to 2020, excluding turkey prices from 2018-2019.

4.3.8 Empirical Approach

The empirical design is based on economic modeling employed in previous studies of pre-committed demand (Hovhannisyan, Bastian, and Devadoss 2021; Hovhannisyan and Gould 2011; Hovhannisyan and Shanoyan 2019). Following Hovhannisyan & Bastian (2022) and Hovhannisyan & Shanoyan (2019), we allocate the pet food category-level budget to specific animal-based proteins. More specifically, we examine five animal-based protein categories: (1) beef, (2) lamb, (3) chicken, (4) turkey, and (5) salmon. The GEASI model is presented as follows:

(4.14)

$$W_{gmt} = \frac{r_g\, P_{gmt}}{I_{mt}} + \left(1 - \frac{\boldsymbol{r}' P_{mt}}{I_{mt}}\right)\left(\sum_{l=0}^{L_1} \beta_{gl} \left(\ln(I_{mt} - \boldsymbol{r}' P_{mt}) - \mathbf{W}' \ln P_{mt}\right)^l + \sum_{k=1}^{N} A_{gj} \ln P_{jmt}\right) + \varepsilon_{gmt}$$

where g indicates the animal-based protein categories; W_{gmt} indicates the expenditure share of category g in market m and year t. We incorporate regional and time fixed effects following a similar approach employed in Hovhannisyan and Bastian (2022) and Zheng et al. (2017).

To identify the proper makeup of the Engel curve for animal-based proteins used in pet food, we adopt the approaches used in Zhen et al. (2013), Hovhannisyan and Bastian (2022), and Rahman et al. (2023). First, we estimate the linear GEASI model and incrementally increase the curvature of the Engel curve's up to quartic, using a likelihood ratio test to evaluate the incremental improvement in the model's explanatory power (Hovhannisyan and Bastian, 2022). Table 4.1 summarizes the diagnostic tests conducted, revealing that the quadratic (L=3) GEASI system offers the best fit for the data, given that it is statistically significant and has the lower

likelihood ratio value. Therefore, we will proceed with our further analysis based on this demand specification.

Table 4.1. Summary of Model Diagnostic Tests

Hypothesis tests for model specification	LR value	df.	p-value
1. Quadratic vs. Linear Engel curves (i.e., $\beta_{i2} = 0, \forall i = 1,...,11$)	66.02	5	0.00
2. Cubic vs. Quadratic Engel curves (i.e., $\beta_{i3} = 0, \forall i = 1,...,11$)	34.09	5	0.00
3. Quadratic vs. Quartic Engel curves (i.e., $\beta_{i4} = 0, \forall i = 1,...,11$)	1.28	5	0.93

4.4 Empirical Results

4.4.1 Pre-committed Demand

Table 4.2 displays the pre-committed and discretionary demand percentages of the annual average consumption for each animal-based protein group. Our research findings indicate that all animal-based protein groups have purchase pre-commitments, except for lamb as the pre-commitment estimate for lamb was not statistically significant. Specifically, the share of pre-committed demand ranges from 6.64% for salmon to 51.51% for beef. The presence of pre-commitment levels indicates that each of these demand components for the animal-based protein groups is inelastic to short-term changes in price, expenditure, and other economic factors. As shown in Table 4.2, more than half of beef pet food consumption is found to be pre-committed, whereas the share of pre-committed consumption is less than 15% for all other animal-based protein groups. The pre-commitment percentages also reveal that pet food containing chicken is estimated to have higher levels of pre-commitment than turkey and salmon, meaning the demand for chicken protein pet food is influenced relatively more by non-economic factors. Conversely,

the demand for pet food containing lamb as a protein source is significantly affected by price and expenditure. Our research highlights that ignoring pre-commitments in the consumption of animal-based protein in pet food can lead to inconsistent structural parameter estimates and inaccurate economic effects.

To identify the pre-committed consumption in pounds, we examine the product of the annual per capita consumption and percentage of pre-consumption share expressed in Table 4.2. Thus, approximately 254.8 pounds (494.6 lbs. × 51.51%) of beef dog food is found to be pre-committed, indicating that 254.8 pounds of beef dog food products will be purchased regardless of the product price and average income level of pet owners. However, 239.8 pounds (494.6 lbs. × 48.49%) of beef dog food product demand is discretionary consumption that is subject to change depending on economic factors (i.e., price and income). Although the share pre-committed consumption of chicken-based dog food is 15%, 195.1 pounds of chicken-based dog food consumption is pre-committed. Pre-committed demand volumes for turkey and salmon are 16.4 pounds and 11.8 pounds respectively. This suggests that purchasers of dog food products based on these ingredients become price and income sensitive more quickly than those who purchase beef- and chicken-based dog food.

Table 4.2. Pre-committed and Discretionary Demand as a Percentage of Annual Average Consumption

ABP group	Annual average per capita consumption (lb.)	Share of pre-committed consumption (%)	Share of discretionary consumption (%)
Beef	494.6	51.51	48.49
Chicken	1305.9	14.94	85.06
Turkey	112.5	14.62	85.38
Salmon	177.3	6.64	93.36

4.4.2 Own-price Elasticity

Parameter estimates from the GEASI model are presented in Table 4.3 below. All price parameter estimates are statistically significant at the 5% significance level. Further, Table 4.4 displays the GEASI-based Marshallian price and expenditure elasticity. Observing the signs of the price coefficients, all diagonal elements are positive, while all non-diagonal price parameters are negative. The GEASI Marshallian and Hicksian own-price and cross-price elasticity estimates are presented in Tables 4.4 and 4.5, respectively. Own-price elasticity estimates are indicated in the diagonal elements. All own-price elasticity estimates are statistically significant and consistent with consumer demand theory, as all diagonal elements in Tables 4.4 and 4.5 are negative (i.e., ranging from -1.05 for beef to -0.58 for turkey). This indicates that quantity demanded for the ABP pet food product decreases with an increase in the product price and vice versa. The Marshallian own-price elasticities for lamb (-0.71), chicken (-0.95), turkey (-0.58), and salmon (-0.82) pet food products indicate inelastic demand, which may be partly due to the

relatively small pre-committed consumptions (0% for lamb, 15% for chicken and turkey, and 7% for salmon). Meanwhile, the own-price elasticity of beef animal-based protein (-1.0) is nearly unitary elastic percentage, meaning the percentage increase in price of beef pet food equals the percentage decrease in quantity demanded for beef pet food products (i.e., a 1% increase in price results in a 1% decrease in the quantity demanded for beef pet food). However, we must keep in mind that pet owners become highly sensitive to price changes only after reaching 51.5% of actual pet food purchasing (i.e., pre-committed quantity). Examining the own-price elasticity estimates in Table 4.5, it seems that the Hicksian own-price elasticities are more inelastic than the Marshallian own-price elasticities, ranging from -0.34 to -0.85. Examining the Hicksian own-price elasticity for pet food products containing chicken proteins, the elasticity estimate is significantly more inelastic at -0.35 as opposed to the -0.95 Marshallian estimate. Like the Marshallian, the Hicksian own-price elasticities for lamb (-0.61), chicken (-0.35), turkey (-0.53), and salmon (-0.76) are inelastic. Conversely, the Marshallian own-price elasticity estimate for beef pet food products was unitary elastic whereas it is -0.85 in the Hicksian estimate. In general, the estimates of the Hicksian own-price elasticity were lower than the Marshallian estimates. Given that the Hicksian and Marshallian elasticity methods vary in the approach to measure price elasticities, as Hicksian focuses on changes in real income and Marshallian assumes constant nominal income, the difference likely attributed to the varying underlying assumptions and focus (Deaton & Muellbauer, 1980). Both Hicksian and Marshallian demand elasticities are useful in understanding how consumers switch from one good to another (substitution effect). However, Marshallian demand elasticity is particularly useful in predicting how customers will react to changes in price and real income (income effect). On the other hand, Hicksian demand elasticity is useful in understanding how consumers react to price changes while keeping their real income

constant (Deaton & Muellbauer, 1980. Therefore, it is recommended to use Hicksian demand elasticity when analyzing the effects of tax changes and subsidies, as they ensure that the consumer is compensated, and the real income is held constant.

4.4.3 Cross-price Elasticity

Cross-price elasticity estimates are presented in the off-diagonal elements and evaluated at the sample means. All Hicksian cross-price elasticities are statistically significant and consistent with consumer demand theory, with positive elasticities for all off-diagonal estimates. As shown in Table 4.5, the Hicksian cross-price elasticity estimates indicates clear existence of substitution patterns among the five animal-based proteins used in pet food, as perceived by pet owners. In contrast, only three of the Marshallian cross-price elasticity estimates indicate the presence of substitution relationships. Specifically, salmon and beef are found to be substitutes (0.02 and 0.13), and beef is substitute to chicken (0.004). Conversely, complimentary patters are indicated among all other ABP Marshallian cross-price elasticity estimates.

4.4.4 Expenditure Elasticity

Table 4.4 also reports the expenditure elasticity estimates for the five animal-based proteins demanded in pet food. All expenditure elasticities are statistically significant at the 5% level, and positive, indicating all normal goods (i.e., consumption increases with an increase in total expenditure). The expenditure elasticity estimates for lamb, turkey, and salmon aligns with the findings of previous pet food demand studies that concluded pet food demand to be expenditure inelastic (Ehlert 1997; Henderson 2013; Schwarz, Troyer, and Walker 2007; Wolf,

Lloyd, and Black 2008), yet beef and chicken are not. However, the magnitude of elasticities is likely to increase as the data becomes more granular (Broda and Weinstein, 2006; Feenstra, 1994). Lamb (0.88), turkey (0.88), and salmon (0.73) are expenditure-inelastic, while beef (1.14) is expenditure-elastic. On the other hand, the expenditure elasticity of chicken (1.02) is unitary elastic.

Table 4.3. Parameter Estimates from the GEASI Expenditure Share Equations

Parameter	Beef	Lamb	Chicken	Turkey	Salmon
Pre-commitment coefficients	**0.0617*** **	-0.0020	**0.0550*** **	**0.0149*** **	**0.0042*** **
	0.0053	*0.310*	*0.0126*	*0.0020*	*0.0016*
Household size	**-0.0001*** **	**-0.0136*** **	**0.0188*** **	**0.0001*** **	**-0.0010*** **
	0.0020	*0.0009*	*0.0060*	*0.0007*	*0.0015*
Number of children	**0.0032*** **	**0.0064*** **	**-0.0188*** **	**-0.0043*** **	**0.0037*** **
	0.0020	*0.0011*	*0.0060*	*0.0011*	*0.0017*
Male	**-0.0033*** **	**-0.0041*** **	**0.0093*** **	**-0.0009*** **	**-0.0012*** **
	0.0013	*0.0010*	*0.0041*	*0.0007*	*0.0012*
Household income	**-0.0047*** **	**0.0032*** **	**-0.0012*** **	**-0.0132*** **	**0.0064*** **
	0.0020	*0.0017*	*0.0062*	*0.0011*	*0.0016*
Real income (β_{i10})	**0.0252*** **	**-0.0126*** **	**0.0148*** **	**-0.0073*** **	**-0.0201*** **
	0.0027	*0.0024*	*0.0041*	*0.0020*	*0.0023*
Real income (β_{i20})	**-0.0023*** **	**0.0018*** **	**-0.0066*** **	**0.0042*** **	**0.0030*** **
	0.0010	*0.0008*	*0.0013*	*0.0007*	*0.0009*
Real income (β_{i30})	**-0.0013*** **	**-0.0007*** **	**0.0015*** **	**-0.0001*** **	**0.0005*** **
	0.0005	*0.0004*	*0.0007*	*0.0004*	*0.0005*
Region 1	**-0.0034*** **	**0.000*** **	**0.0062** **	**0.0011*** **	**0.0016*** **
	0.0048	*0.0015*	*0.0126*	*0.0022*	*0.0024*
Region 2	**0.0226*** **	**-0.0011*** **	**0.1096** **	**-0.0034*** **	**-0.0034*** **
	0.0067	*0.0060*	*0.0228*	*0.0062*	*0.0024*
Region 3	**-0.0088*** **	**-0.0034*** **	**0.0198*** **	**-0.0085*** **	**-0.0093*** **
	0.0051	*0.0033*	*0.0136*	*0.0038*	*0.0034*
Intercept	**0.1772*** **	**0.1054*** **	**0.5926*** **	**0.0526*** **	**0.0722*** **
	0.0016	*0.0015*	*0.0023*	*0.0016*	*0.0014*

Table 4.3. Parameter Estimates from the GEASI Expenditure Share Equations (cont.)

Parameter	Beef	Lamb	Chicken	Turkey	Salmon
Price (α_{1j}) beef	**-0.0039*** **	**-0.0032*** **	**0.0049*** **	**-0.0038*** **	**0.0061*** **
	0.0020	*0.0010*	*0.0020*	*0.0011*	*0.0014*
Price (α_{2j}) lamb		**0.0303*** **	**-0.0199*** **	**-0.0046*** **	**-0.0026*** **
		0.0013	*0.0016*	*0.0010*	*0.0012*
Price (α_{3j}) chicken			**0.0398*** **	**-0.0128*** **	**-0.0119*** **
			0.0028	*0.0013*	*0.0020*
Price (α_{4j}) turkey				**0.0248*** **	**-0.0035*** **
				0.0012	*0.0012*
Price (α_{5j}) salmon					**0.0012*** **
					0.0013

Note: The standard errors are in parenthesis.: *** p < 0.01; ** p < 0.05; * p < 0.10

Table 4.4. GEASI-Based Marshallian Price and Expenditure Elasticity Estimates

ABP	Beef	Lamb	Chicken	Turkey	Salmon	Expenditure
Beef	**-1.0475*** **	**-0.0338*** **	**-0.0558*** **	**-0.0305*** **	**0.0239*** **	**1.1437** **
	0.0119	*0.0060*	*0.0113*	*0.0064*	*0.0076*	*0.0155*
Lamb	**-0.0093*** **	**-0.7057*** **	**-0.1166** **	**-0.0357*** **	**-0.0155*** **	**0.8828** **
	0.0090	*0.0131*	*0.0149*	*0.0096*	*0.0107*	*0.0221*
Chicken	**0.0040*** **	**-0.0369*** **	**-0.9466*** **	**-0.0235*** **	**-0.0223*** **	**1.0254*** **
	0.0035	*0.0030*	*0.0054*	*0.0023*	*0.0034*	*0.0070*
Turkey	**-0.0427** **	**-0.0636** **	**-0.1426** **	**-0.5800** **	**-0.0497** **	**0.8786** **
	0.0182	*0.0169*	*0.0245*	*0.0214*	*0.0198*	*0.0334*
Salmon	**0.1307** **	**-0.0058** **	**-0.0029** **	**-0.0315** **	**-0.8160** **	**0.7256** **
	0.0185	*0.0159*	*0.0305*	*0.0164*	*0.0027*	*0.0311*

Notes: Elasticities are evaluated at the sample mean values. Standard errors are in parenthesis.:

*** p < 0.01; ** p < 0.05; * p < 0.10

Table 4.5. GEASI-Based Hicksian Price Elasticity Estimates

ABP	Beef	Lamb	Chicken	Turkey	Salmon
Beef	**-0.8466*** **	**0.0894*** **	**0.6113*** **	**0.0382*** **	**0.1078*** **
	0.0111	*0.0057*	*0.0113*	*0.0062*	*0.0077*
Lamb	**0.1458*** **	**-0.6106*** **	**0.3983** **	**0.0173*** **	**0.0492*** **
	0.0093	*0.0118*	*0.0150*	*0.0092*	*0.0109*
Chicken	**0.1841*** **	**0.0736*** **	**-0.3486*** **	**0.0381*** **	**0.0528*** **
	0.0034	*0.0028*	*0.0048*	*0.0022*	*0.0034*
Turkey	**0.1116** **	**0.0311** **	**0.3699** **	**-0.5273** **	**0.0147** **
	0.0182	*0.0165*	*0.0216*	*0.0205*	*0.0198*
Salmon	**0.2582** **	**0.0723** **	**0.4203** **	**0.0120** **	**-0.7628** **
	0.0185	*0.0160*	*0.0271*	*0.0162*	*0.0403*

Notes: Elasticities are evaluated at the sample mean values. Standard errors are in parenthesis.:
*** p < 0.01; ** p < 0.05; * p < 0.10

4.5 Discussion

4.5.1 Dog Food Pricing and Taxation Implications

The findings of this study indicate the presence of pre-committed demand should be accounted for in policies and pricing strategies of pet food companies. There exists a potential level of quantity demanded for ABP dog food products that customers will purchase regardless to the price and income, including 52% of beef consumption, 15% of chicken dog food consumption, 14% of turkey consumption, and 6% of salmon consumption. Given the differences in pre-commitment levels and elasticity estimates of the ABP dog food categories, policies and product price changes will have a differential impact on the consumption levels of each category. For instance, the quantity demanded of beef- and chicken-based dog food will not respond to price changes until volume levels of 254.8 pounds and 195.1 pounds are reached respectively. Thereafter, consumers of beef-based dog food will exhibit large shift in the quantity demanded of beef-based dog food, whereas the discretionary demand for chicken will not exhibit large shifts in the quantity demanded according to the Hicksian own-price elasticity estimates. In contrast, the pre-commitment volume levels of turkey (16.4 lbs.) and salmon (11.8 lbs.) indicate that turkey and salon will respond quicker to changes in the price of these ABP dog foods than that of chicken- and beef-based dog food customers. Once the turkey and salmon pre-commitment levels are reached, salmon will have a larger shift in the quantity demanded than turkey.

4.5.2 Health-related Implications

Opportunities exist for policy makers to address pet obesity concerns through promotion of healthier pet food products that are lower in fat content. One approach to achieving this is through taxation of pet food products with higher fat content levels, specifically high-fat ABP pet food products. To gain insights into the potential impact of a tax on animal-based protein pet food products on pet food consumption and obesity control, we examine the elasticity and pre-committed demand estimates. Importantly, our suggested taxes assume a consumption tax at the retail level that is only endured by consumers. Given that animal-based proteins used in pet food is the by-product of human food production (Hill, 2022), imposing taxation on the ABP at the farm and/or production level can potentially alter prices and purchasing habits of human food products in addition to the intended pet food demand.

To reduce pet obesity levels, public policy should be designed to encourage pet owners to switch from high fat products, like beef, salmon, and lamb, to leaner products such as chicken and turkey. Figure 4.2 highlights that ABP pet food products containing higher fat content are priced lower on average than leaner alternatives. Our elasticity estimates suggest that if the cost of high-fat products like beef, salmon, and lamb increases, customers may switch to chicken pet food products, as chicken has the highest cross-price elasticity for all other ABP substitutes, shown in Table 4.5. Beef is the most consumed pet food among high-fat ABP products and is also the most elastic product. Thus, increasing the price through taxation is likely to result in pet owners switching to lower-fat chicken products. Although the Marshallian cross-price elasticity results in Table 4.4 suggest a potential switch to salmon pet food products (which are also high in fat content), simultaneous taxing of beef and salmon products may be more effective in curbing consumption to chicken and/or turkey. An important pre-condition to the potential

change in demand from taxation of ABP is the pre-committed demand levels of beef and salmon. Specifically, 52% of beef pet food consumption is pre-committed, meaning the changes in beef demand due to the rising prices from taxes will occur only after the pre-commitment level is reached. Likewise, salmon demand will only be affected after the 7% pre-commitment level is reached.

4.6 Summary and Conclusion

The pet food industry is rapidly growing, with an increasing demand for specialized pet diets that prioritize nutritional value, high-quality ingredients, and pet health and wellness (Waters 2021; Wagoner et al. 2022). This shift in pet food demand has led to a rise in demand for high-protein products, particularly animal-based proteins (ABP). Despite the growing demand and varying customer preferences in the pet food industry, there is a lack of peer-reviewed studies that examine the elasticities of pet food demand in general and specifically the demand for ABP. The aim of this study is to bridge this gap in the literature by conducting a comprehensive pet food demand analysis that considers potential pre-commitment. The study combines market-level pet food consumption data with recent advances in consumer theory to investigate pet food demand structure and to gain insights into pet food buyers' preferences and purchasing behavior regarding products containing five animal-based proteins: beef, lamb, chicken, turkey, and salmon.

The main results indicate that pet owners select from among pet food products containing one of the five animal-based proteins considered, and the Hicksian elasticity matrix further confirms that these are predominantly substitute goods. In addition, our results further find the presence of pre-committed demand in all ABP pet food products except lamb. Specifically, a

percentage of the consumption of beef (52%), chicken (15%), turkey (15%), and salmon (7%) pet food products are due to pre-committed demand, meaning the reported inelastic and elastic demand does not apply until the pre-committed demand levels are reached.

This study extends the empirical literature on U.S. pet food demand by considering pre-commitments. Given the growing importance of the pet food industry and shifting consumer preferences, the relevance of this study should be of interest to policymakers. It may prove useful in informing public policy decisions in light of the rising demand for specialized pet food ingredients and animal-based proteins. Understanding the demand structure pet food can also help industry decision-makers predict customer response to price changes in products containing the five animal-based proteins considered in this study.

Future research should incorporate the use of price instruments derived from disaggregated manufacturer, wholesaler, and retail-level cost data to address potential price endogeneity caused by the simultaneous determination of food supply and demand (Hovhannisyan and Bastian, 2022). In addition, future research should incorporate other variety of animal-based and non-animal-based proteins to provide a more comprehensive analysis of the pet food demand structure and potential price, income, and substitution effects. Lastly, future studies should examine individual level disaggregate pet food consumption for a more accurate elasticity assessment and implications.

Chapter 5 - Conclusion

Despite the growing pet food industry, there is limited publicly available literature to guide product development and marketing decisions. Therefore, there is a need for increased understanding of industry needs and high-quality research to help decision-makers capture the industry's profit potential. In this study, we identified a list of high-priority topics expressed by pet food decision-makers in the areas of raw materials, production, and marketing. We found that future research should focus on improving the quality and availability of raw materials, enhancing production capabilities, and understanding consumer demand and preferences.

A rising concern expressed in the consensus of pet food literature and industry decision-makers, linked to the three research needs above, is the need to reduce pet obesity levels. Pet owners can reduce pet obesity by properly understanding and applying feeding and exercise management. This includes feeding lower calorie products and reducing feeding frequency, as well as increasing the duration and frequency of medium and high-intensity weekly exercises. Pet food companies can contribute by developing low-calorie product designs, pre-packaged portions to aid in proper feeding amounts, and increasing customer knowledge of proper feeding management habits. Lastly, policymakers can potentially affect obesity through public policy to promote customers to purchase healthier, low-fat pet food options. The findings in this study suggest that pre-committed demand levels are present suggest that higher-fat content pet food products are more affordable than leaner products. Implementing a tax on higher-fat content products can potentially promote customers to switch to lower-fat substitute products. However, since pre-committed demand levels were found to be present in pet food demand, customer response to price changes will only occur after pre-commitment levels are met.

Furthermore, the findings provide insight into how direct industry stakeholders can assist in reducing levels of obesity in pets. While the findings are beneficial, this study is not without limitations. The dataset covering pet obesity has low variability among the body condition scores, which could potentially limit the ability to accurately observe feeding management dynamics and make accurate inferences. Another cause for concern is the aggregation of pet food demand data, which could potentially reduce the accuracy of predicting the pet food demand structure. Although we predict pet food price and expenditure elasticities at the regional level, a more comprehensive analysis could be achieved through examining consumer/household level data. In addition, we exclude non-mutually exclusive animal-based protein products (ABP) and products that do no mention the ABP in the product description. Future research should include additional categories for combination ABP dog food products to capture substitution and complimentary effects. Finally, there is potential price endogeneity introduced by simultaneous examination of supply and demand, particularly in the absence of disaggregated manufacturer and retail supply data. Further studies should explore ways to address these limitations.

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Appendix A - Pet Food Industry Needs Survey

Thank you for your participation in the Pet Food Industry Research Needs Survey. The information obtained in this survey will help to identify the most important and relevant research areas for addressing challenges faced by pet food industry decision makers. This survey is part of a larger study designed to identify and generate research insights needed to inform decisions in the Pet Food Industry. The study will be conducted by Lonnie Hobbs, Jr., Dr. Greg Aldrich, and Dr. Aleksan Shanoyan. Participation in the survey is voluntary. You may discontinue participation in the survey at any time without penalty.

Demographics

1. Please indicate your highest level of education.

- ○ High School diploma / GED
- ○ Associate Degree / Trade School Degree
- ○ Bachelor's degree
- ○ Master's Degree or M.B.A.
- ○ Ph.D. or M.D.

2. Please indicate your business type.

- ○ Pet Food Brand Owner/marketer
- ○ Manufacturer of Pet Food
- ○ Manufacturer of Pet Food & Treats
- ○ Manufacturer of Pet Treats
- ○ Private Label Manufacturer/Co packer
- ○ Other (please specify): _____

3. Please indicate your company's range number of employees.

- ○ 0-24
- ○ 25-49
- ○ 50-99
- ○ 100-1,000
- ○ Over 1,000

4. Please indicate your job function.

- ○ Corporate/general management
- ○ Marketing/sales
- ○ Pet food production management
- ○ QC/QA/Food safety
- ○ Research & development
- ○ Product development
- ○ Other (please specify): _____

5. Please indicate how often you have made decisions within your company related to the following factors over the last 3-months.

- ○ Raw Materials _____
- ○ Production _____
- ○ Marketing _____

6. Rank the following factors in terms of their importance for the success of your company.

Use the cursor to drag each factor to the correct position.
(Rank: 1=most important, 3=least important)
_____ Raw Materials
_____ Production
_____ Marketing

Raw Materials

7. Rate the following areas related to raw materials based on the **need for research insights** to inform your company's decisions.

Use the cursor to click or drag or the slider to the correct position.

	No Need for research insights / Very High Need for research insights 0 1 2 3 4 5 6 7 8 9 10
Availability / consistent supply of raw materials	
Cost of raw materials	
Quality of raw materials	
Governmental regulations of raw materials	
Other (Please Specify)	

8. Please specify your **primary source** for obtaining relevant research insights regarding raw materials.

- ○ Information not available
- ○ In-house research
- ○ Private consultant
- ○ Industry association (e.g., Pet Food Institute)
- ○ University research
- ○ Trade publication (e.g., Petfood Industry magazine, whole-dog-journal.com, etc.)
- ○ Other (Please Specify) _____

9. Describe the most important challenge related to **raw materials** faced by your company.

_____

_____

_____

_____

_____

10. Describe the key information gaps related to **raw materials** faced by your company?

_____

_____

_____

_____

_____

Production

11. Rate the following areas related to <u>production</u> based on the need for research insights to inform your company's decisions.

Use the cursor to click or drag or the slider to the correct position.

No need for research insights										Very High Need for research insights
0	1	2	3	4	5	6	7	8	9	10

Processing methods/technology	
Management methods/processes	
Approaches for attracting, recruiting, and retaining talent	
Risk management	
Governmental regulations/compliance	
Facilities	
Geography / Location	
Other (Please Specify)	

12. Please specify your **primary source** for obtaining relevant research insights regarding production.

- ○ Information not available
- ○ In-house research
- ○ Private consultant
- ○ Industry association (e.g., Pet Food Institute)
- ○ University research
- ○ Trade publication (e.g., Petfood Industry magazine, whole-dog-journal.com, etc.)
- ○ Other (Please Specify) _____

13. Describe the most important challenge related to **production** faced by your company.

_____

_____

_____

_____

_____

14. Describe the key information gaps related to **production** faced by your company?

_____

_____

_____

_____

_____

Marketing and Distribution

15. Rate the following areas related to marketing and distribution based on the **need for** research insights to inform your company's decisions.

Use the cursor to click or drag or the slider to the correct position.

	No need for research insights									Very High Need for research insights
	0	1	2	3	4	5	6	7	8	9	10
Market and competitor intelligence											
Attracting and retaining customers											
Forecasting consumer demand											
Forecasting consumer tastes and preferences											
Coordinating supply chain and distribution											
Validation of claims											
Other (Please Specify)											

16. Please specify your **primary source** for obtaining relevant research insights regarding marketing and distribution.

- ○ Information not available
- ○ In-house research
- ○ Private consultant
- ○ Industry association (e.g., Pet Food Institute)
- ○ University research
- ○ Trade publication (e.g., Petfood Industry magazine, whole-dog-journal.com, etc.)
- ○ Other (Please Specify) _____

17. Describe the most important challenge related to **marketing and distribution** faced by your company.

_____

_____

_____

_____

_____

18. Describe the key information gaps related to **marketing and distribution** faced by your company?

_____

_____

_____

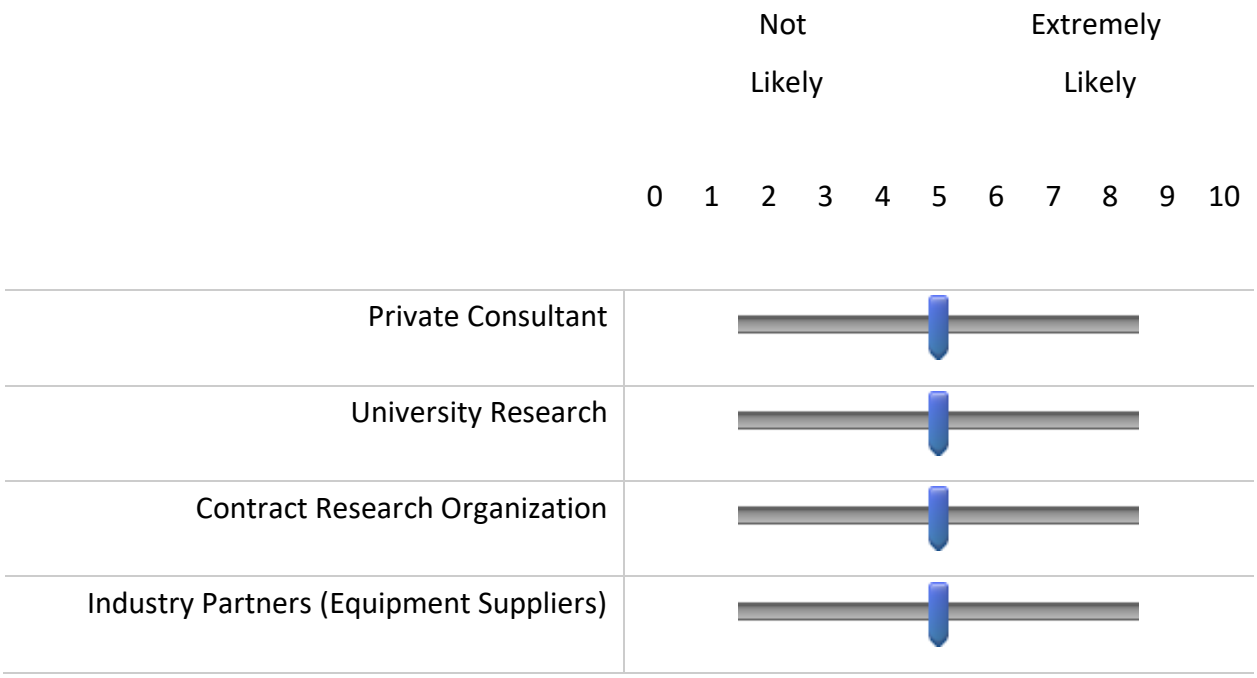
_____

_____

External Research Utilization

19. Please indicate how likely you will reach out to or collaborate with the following parties to obtain research insights during the next 1-3 years.

Use the cursor to click or drag or the slider to the correct position.



Industry Trends

20. Describe the most important product/market trend in the Pet Food Industry currently?

_____

_____

_____

_____

_____

21. What problem/challenge do you feel will be of most importance to the Pet Food Industry over the next 5-10 years?

_____

_____

_____

_____

_____

Additional comments:

_____

_____

_____

_____

_____

Your response has been recorded.

Thank you for your time and valuable information.

We wish you and your company the best!

Appendix B - Pet Food Literature Reading List

Appendix B -Table 5.1. Pet Food Academic Literature

Title	Author	Year	Primary Area	Open Gaps	URL
Evaluating the Supply Chain of Animal Protein-Based Pet Food Ingredients and International Trade of Pet Food	Hill	2022	Raw materials	Estimation of the value of animal-based protein ingredients in pet food and factors affecting pet food trade.	https://krex.k-state.edu/dspace/handle/2097/42387
An Alternative Approach to Evaluate the Quality of Protein-Based Raw Materials for Dry Pet Food	Motegoive et al.	2021	Raw materials	Identification of digestibility indexes of the different raw materials used for dry pet food production	https://www.mdpi.com/2076-2615/11/2/458
The Global Environment Paw Print of Pet Food	Alexander et al.	2020	Raw materials Production	There is a lack of research and data surrounding environmental paw prints from pet food. Adoption of human plant-based diets should be extended into companion animals.	https://www.sciencedirect.com/science/article/pii/S0959378020307366
A Dog Food Recommendation System Based on Nutrient Suitability	Song. & Kim	2020	Raw materials Marketing/Distribution	Further evaluation and improvements of content-based dog food recommendation algorithms are needed to assist pet owners in determining suitable pet food to improve pet health conditions.	https://onlinelibrary.wiley.com/doi/full/10.1111/exsy.12623

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Antioxidant Performances of Corn Gluten Meal and DDGS Protein Hydrolysates in Food, Pet Food, and Feed Systems	Hu et al.	2020	Raw materials	Improved product storage stability.	https://www.sciencedirect.com/science/article/pii/S2666154320300119
Special Topic: The Association Between Pulse Ingredients and Canine Dilated Cardiomyopathy: Addressing the Knowledge Gaps Before Establishing Causation	Mansilla et al.	2019	Raw materials	Increased knowledge of processing methodologies and nutrient interactions among ingredient combinations.	https://academic.oup.com/jas/article/97/3/983/5279069
Bacteriophages Safely Reduce Salmonella Contamination in Pet Food and Raw Pet Food Ingredients	Soffer et al.	2016	Raw materials	Improved safety of raw pet food ingredients and production.	https://www.tandfonline.com/doi/full/10.1080/21597081.2016.1220347
Natural Pet Food: A review of Natural Diets and their Impact on Canine and Feline Physiology	Buff, Carter, & Kersey	2014	Raw materials	Understanding of natural pet food diets and their effect on growth and performance, nutrient availability, digestibility, and product safety	https://academic.oup.com/jas/article/92/9/3781/4702209
Myths and Misperceptions About Ingredients Used in Commercial Pet Foods	Laflamme et al.	2014	Raw materials	Indicators of ingredient quality cannot be included on product labels. Therefore, true food quality indicators such as nutrient profile and digestibility are only known by companies.	https://www.vetsmall.theclinics.com/article/S0195-5616(14)00047-3/fulltext

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Select Corn Coproducts from the Ethanol Industry and their Potential as Ingredients in Pet Foods	de Godoy et al.	2009	Raw materials	Increased nutritional information on novel ingredients and product claims.	https://academic.oup.com/jas/article/87/1/189/4731181
Mycotoxins and the Pet Food Industry: Toxicological Evidence and Risk Assessment	Boermans & Leung	2007	Raw materials	Address and assess of risk and safety of mycotoxins in pet food.	https://www.sciencedirect.com/science/article/pii/S0168160507003935?casa_token=SmG_xu0rR3wAAAAA:0677ad5UCrMbJjSBPSj5Cau35p9PAdzrsRNm65TeyKERMp5lepS8gLgV7oEqKup0iawOY_ipyIw
Dry Pet Food Flavor Enhancers and Their Impact on Palatability: A Review	Samant et al.	2021	Production	Use of aromas commonly related to human foods and traditional palatability-enhancing agents can be potentially valuable in pet food acceptance.	https://www.mdpi.com/2304-8158/10/11/2599
Additives in Pet Food: Are They Safe?	Craig, J.M.	2021	Production Raw materials	Updated processing strategies and technologies are needed to establish and ensure product safety processed food production.	https://onlinelibrary.wiley.com/doi/full/10.1111/jsap.13375
Dry Pet Food Flavor Enhancers and Their Impact on Palatability: A Review	Samant et al.	2021	Production	Use of aromas commonly related to human foods and traditional palatability-enhancing agents can be potentially valuable in pet food acceptance.	https://www.mdpi.com/2304-8158/10/11/2599

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Sustainability and Pet Food: Is There a Role for Veterinarians?	Acuff et al.	2021	Production	Pet owners do not fully understand the impacts purchasing decisions have on sustainability.	https://www.vetsmall.theclinics.com/article/S0195-5616(21)00020-6/fulltext
A Literature Review on Vitamin Retention During the Extrusion of Dry Pet Food	Morin, Gorman, & Lambrakis	2021	Production	Improved retention of vitamins during extrusion process.	https://www.sciencedirect.com/science/article/pii/S0377840121001619?casa_token=D3TFs5BnmbcAAAAA:0aAfNthGYalkQa31kJVMJNo4TizUJE85L9HkcMnrbrGnXNfswGeO0jaKX29UEVnTOBWvEqANnIM
Effects of Thermal Energy on Extrusion Characteristics, Digestibility and Palatability of a Dry Pet Food for Cats	Baller et al.	2021	Production	Improved nutrient retention through generalizable extrusion process among manufacturers.	https://onlinelibrary.wiley.com/doi/full/10.1111/jpn.13606?casa_token=flOSZlE9UTMAAAAA%3AVz722HpjkhxkPF3tKUIql4upaCyxVN_yGQJnKrz8wSQZ_UL00n7BhFmsqJdkYZTfExxqvojWpf4i--s
Pet Food Quality Assurance and Safety and Quality Assurance Survey within the Costa Rican Pet Food Industry	Leiva et al.	2019	Production	Improved pet food formulations to account for the loss of nutrients during extrusion process.	https://www.mdpi.com/2076-2615/9/11/980
A Comparative Analysis of Mycotoxin Contamination of Supermarket and Premium Brand Pelleted Dog Food in Durban, South Africa	Singh & Chutu	2017	Production	Improved processing and packaging technology can potentially reduce the presence of mycotoxins in pet food.	https://journals.co.za/doi/abs/10.4102/jsava.v88i0.1488

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Pet Food Palatability Evaluation: A Review of Standard Assay Techniques and Interpretation of Results with Primary Focus on Limitations	Aldrich & Koppel	2015	Production	There is a need to develop methods that would help understand and improve palatability related issues or provide better models to predict cat and dog food selection.	https://www.mdpi.com/2076-2615/5/1/43
The Effects of Cooking Process and Meat Inclusion on Pet Food Flavor and Texture Characteristics	Koppel et al.	2014	Production	Assessment of flavor, odor, and texture characteristics associations with palatability.	https://www.mdpi.com/2076-2615/4/2/254
Pet Food Safety: A Shared Concern	Buchanan et al.	2011	Production	Identification of new sources of nutrients to enhance nutritional well-being of pets.	https://www.cambridge.org/core/journals/british-journal-of-nutrition/article/pet-food-safety-a-shared-concern/A2BBC59F8ABFE6280F7A36249CE0DB14
The Pet Exposure Effect: Exploring the Differential Impact of Dogs Versus Cats on Consumer Mindset	Jia, Yang, & Jang	2022	Marketing/Distribution	Need for understanding the strength of influence of pets versus people on consumer behavior.	https://journals.sagepub.com/doi/full/10.1177/00222429221078036
Is there a Market for Upcycled Pet Food?	Ye et al.	2022	Marketing/Distribution	Identifying consumer purchasing behavior and price response to branding when accounting for political ideology of pet owners.	https://www.sciencedirect.com/science/article/pii/S0959652622005960?casa_token=Q8RzbG3_IIMAAAAA:dky2wAI3BM-xOp2_UDs69jdkfjHn-NxebvBqEM-xed79aBGSqvYvjJ5DhlVWvYsKjG1_Swzq-X4

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Analysing the Impact of COVID 19 and Firm Performance: A Case Study of Pet Foods Firms in Malaysia	Cherz & Rahman	2022	Marketing/Distribution	Improved marketing and business strategy tools to evaluate pet food company performance.	http://eprints.utar.edu.my/4448/1/1900651__hazel_chua.pdf
A New Market for Pet Food in China: Online Consumer Preferences and Consumption	Xiao, Wang, & Li	2021	Marketing/Distribution	Identify if there is a difference in online versus offline pet food purchasing behavior.	https://www.tandfonline.com/doi/abs/10.1080/10971475.2021.1890360
Profiling Italian Cat and Dog Owners' Perceptions of Pet Food Quality Traits	Vinassa et al.	2020	Marketing/Distribution	Identification of factors that influence dog and cat owners' perceptions of pet food quality.	https://link.springer.com/content/pdf/10.1186/s12917-020-02357-9.pdf
Determinants of Pet Food Purchasing Decisions	Schleicher, Cash, & Freeman	2019	Marketing/Distribution	Improved understanding of the underlying motivations of pet food purchases and pet diet selections.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6515811/
Analysis of Customer Perception of Product Attributes in Pet Food: Implications for Marketing and Product Strategy	Hobbs, Jr.	2019	Marketing/Distribution	Improved understanding of customer perceptions of product attributes, attribute category classifications, and customer purchasing behavior.	https://krex.k-state.edu/dspace/handle/2097/40076
An Analysis of Pet Food Label Usage	Lemke et al.	2015	Marketing/Distribution	Improvement pet food labeling and education of pet owners about benefits of label	https://www.cabdirect.org/cabdirect/abstract/20153441457

Appendix B -Table B.1 Pet Food Academic Literature (cont.)

Title	Author	Year	Primary Area	Open Gaps	URL
Feeding Fido: Changing Consumer Food Preferences Bring Pets to the Table	Kumcu & Woolverton	2014	Marketing/Distribution	Improved understanding of customer purchasing behaviors and ways to leverage technology to reach younger age pet owners.	https://www.tandfonline.com/doi/full/10.1080/10454446.2012.715575?casa_token=LPAKtZlI_wYAAAAA%3AjE2rVunPOPp_pBphKPGBskU9JKy3d1dopzdcgOba-0CcyW3ssk0WE6E9Ja5IJcnnZnZqd_XN--vyaA
Sensory Analysis of Pet Foods	Koppel	2014	Marketing/Distribution	Improved analysis and understanding of personality and environmental factor to further understand customer acceptance to pet food.	https://onlinelibrary.wiley.com/doi/abs/10.1002/jsfa.6597?casa_token=t5nsJMHARzMAAAAA:Wv6OhrsmtwPKH-TFATel-KSbLDQc9M_8-uPVsQdcKkJg56dGzR-LaSg07rVDTptDYrhU8YK_HC0XvNE
Do They Buy for Their Dogs the Way They Buy for Themselves?	Tesform & Birch	2010	Marketing/Distribution	Need for research to understand why dog owners choose certain brands over others, and how behavioral connection influences purchasing decisions.	https://onlinelibrary.wiley.com/doi/full/10.1002/mar.20364
Animal House: Economics of Pets and the Household	Schwarz, Troyer, & Walker	2007	Marketing/Distribution	Improved understanding of pet owner spending habits and factors driving spending over time.	https://faunalytics.org/wp-content/uploads/2015/05/Citation421.pdf

Appendix B -Table 5.2. Pet Food Non-Academic Literature

Title	Source	Year	Open Gaps	URL
Global Pet Food Market Size & Share Report	Grand View Research	2022	Need for insight to address supply issues, flow of raw materials, and forecast product demand.	https://www.grandviewresearch.com/industry-analysis/pet-food-industry
North America – Pet Healthcare	Marketline	2022	Need for product innovation to meet customer demands and increase competitive advantage.	https://advantage-marketline-com.er.lib.k-state.edu/Analysis/ViewasPDF/north-america-pet-healthcare-155740
Pet Food Market Share, Trends, Report |2022-27|	Mordor Intelligence	2022	Need for insight to address supply issues, use of human grade ingredients, online purchasing behavior, and forecast product demand.	https://www.mordorintelligence.com/industry-reports/global-pet-food-market-industry
Challenges Continue to Keep pet Food Manufacturers on Their Toes | Pet Food Processing	Petfood Processing	2022	Need for insight to address supply issues, flow of raw materials, and labor shortages.	https://www.petfoodprocessing.net/articles/15947-challenges-continue-to-keep-pet-food-manufacturers-on-their-toes
Pet Food Labor Challenges and Automation Solutions	Petfood Industry.com	2022	Need for insight to address labor shortages, supply chain issues, and processing innovations.	https://www.petfoodindustry.com/articles/11148-pet-food-labor-challenges-and-automation-solutions
Pet Food Institute Explains Food Shortages, Inflation Impacts	Pet Food Institute	2022	Need for insight to address supply issues, labor shortages, raw materials shortages, and forecast product demand.	https://www.ktre.com/2022/07/25/pet-food-institute-explains-food-shortages-inflation-impacts/
Pet Food Market Trends	PetfoodIndustry.com	2022	Need for insight to address supply issues, use of human grade ingredients, identify alternative protein sources, and forecast product demand.	https://www.petfoodindustry.com/topics/222-pet-food-market-trends
Industry at a Glance – OD4347 Pet Food Production	IBIS World	2021	Need for product innovation to increase nutritional benefits, identify raw material alternatives, and forecast and meet future demand.	https://my-ibisworld-com.er.lib.k-state.edu/us/en/industry-specialized/od4347/industry-at-a-glance

Appendix B -Table B.2 Pet Food Non-Academic Literature (cont.)

Title	Source	Year	Open Gaps	URL
Baby, Children, and Pet Products: Consumer Behaviour is Driving Innovation in Key Sectors	Marketline	2021	Need for increased for increased human grade ingredients, product transparency, ingredient quality, and sustainable packaging.	https://advantage-marketline-com.er.lib.k-state.edu/Analysis/ViewasPDF/baby-children-and-pet-products-consumer-behaviour-is-driving-innovation-in-key-sectors-137681
Pet Supplies – US - 2021	Mintel Group Ltd.	2021	Need for insight to improve product and ingredient quality, increase safety standards, product transparency, and forecast customer purchasing behavior.	https://reports-mintel-com.er.lib.k-state.edu/display/1086999/?fromSearch=%3Ffreetext%3Dpet%2520food&highlight#hit1
Pet Food Report 2021	Statista	2021	Need for insight to address supply issues and forecast future product demand.	https://www-statista-com.er.lib.k-state.edu/study/48838/pet-food-report/
What You Need to Know About the Pet Food Shortage	Animal Health Clinic of Funkstown	2021	Need for insight to address supply issues, flow of raw materials, and meet rising demand.	https://funkstownvet.com/blog/what-you-need-to-know-about-the-pet-food-shortage/
Pet Food Processors Cope with Labor Shortages Amid Growing Product Demand	Petfood Processing	2021	Need for insight to address labor shortages, supply chain issues, and meet rising demand.	https://www.petfoodprocessing.net/articles/15323-pet-food-processors-cope-with-labor-shortages-amid-growing-product-demand
Global Pet Food Sales	Statista	2017	Need for product innovation to meet customer demands and increase competitive advantage.	https://www.statista.com/statistics/253953/global-pet-food-sales/

Appendix C - Pet Obesity Survey

Thank you for your participation in the Pet Obesity Survey. The information obtained in this survey will help to identify and address factors contributing to overweight and obesity in pets. This survey is part of a larger study designed to identify and generate research insights needed to inform decisions in the pet food industry related to the design of pet food and treat products that are more conducive to healthy weight. The study will be conducted by Lonnie Hobbs, Jr., Dr. Greg Aldrich, and Dr. Aleksan Shanoyan. Collection of survey information will be used in Lonnie Hobbs, Jr.'s PhD dissertation research.

Participation in the survey is voluntary. You may discontinue participation in the survey at any time without penalty.

Owner Characteristics

In this section, we would like to know more about you, the pet owner.

Q1 Please specify your gender.

- ○ Male
- ○ Female
- ○ Prefer not to specify

Q2 Please indicate your age.

- ○ Under 20 years
- ○ 21 - 24 years
- ○ 25 - 32 years
- ○ 33 - 40 years
- ○ 41 - 48 years
- ○ 49 - 56 years
- ○ 57 - 64 years
- ○ 65 - 75 years
- ○ Above 75 years

Q3 Which category best describe your household annual income level?

- ○ Less than $20,000
- ○ $20,000 - $40,999
- ○ $41,000 - $59,999
- ○ $60,000 - $85,999
- ○ $86,000 - $99,999
- ○ $100,000 - $119,999
- ○ $120,000 - $139,999
- ○ $140,000 - $164,999
- ○ $165,000 or more

Q4 Please indicate your highest level of education.

- ○ Some high school
- ○ High school diploma
- ○ Some college or trade
- ○ College degree
- ○ Some graduate education
- ○ Graduate degree or equivalent

Q5 In which state do you currently reside? (Use the dropdown below to select your state)

▼ Alabama

This question has a drop-down menu with all 50 US states listed and an "I do not reside in the US" option available.

Now, we would love to know more about your pet.

Q6 How many dogs do you have?

_____

To answer the following questions, please refer to the dog with the name closest to the beginning of the alphabet to answer the remaining questions in this survey.
(e.g., if your dog's names are Aaron and Donald, please answer the remaining questions in reference to Aaron)

Q7 What is your dog's name?

_____

Q8 What is your dog's breed?

_____

Q9 What is your dog's sex and reproductive status?

- ○ Male - intact
- ○ Male - neutered
- ○ Female - intact
- ○ Female - spayed

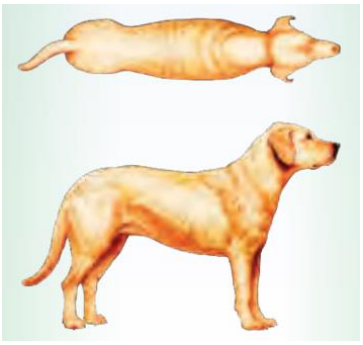
Q10 Please specify your dog's age in the text box below. Specify in years **AND** months (e.g., 1 year and 5 months).

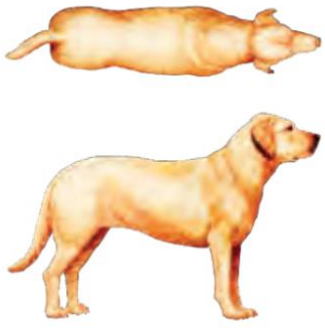
- ○ Years _____
- ○ Months _____

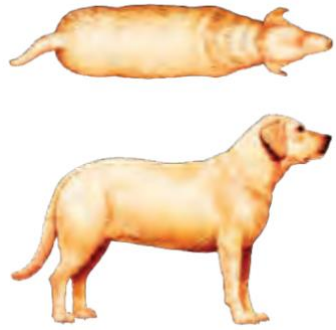
Q11 What is your dog's weight? (Specify in lbs.) If you are uncertain, it is ok to provide a ballpark estimate.

_____

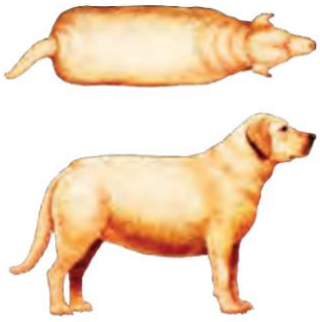
Q12 Based on the pictures provided below, please select the body condition that best matches the condition of your dog.

○ 1 

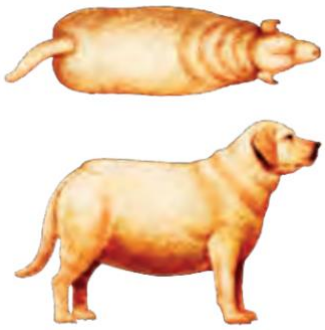
○ 2 

○ 3 

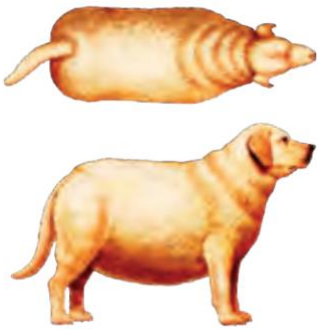
4



5



6



Q13 Please specify where your dog spends most of the day.

- ○ Exclusively indoors
- ○ Mostly indoors
- ○ Equal amounts indoors and outdoors
- ○ Mostly outdoors
- ○ Exclusively outdoors

Primary Dog Food

Now, tell us a little bit about your dog's diet.

Q14 Describe your dog's **primary food**?

- ○ Dry kibbles (croquettes)
- ○ Wet food (canned, pouch, or tray)
- ○ Fresh (cooked) food (commercial or home prepared)
- ○ Raw food (commercial or home prepared)
- ○ Other _____

Q15 Please type the brand name of your dog's primary food in the text boxes below. Please specify the top three brands used from (1) most frequently used to (3) least frequently used. For

each brand, please specify the product name and the formulation type. (e.g., Blue Buffalo, Life protection, chicken, and rice recipe)

	Brand Name	Product Name	Formulation/ Recipe
1			
2			
3			

Q16 Please name the main ingredients used in your dog's primary meal from (1) most frequently used to (3) least frequently used. (e.g., raw chicken, grains, etc.)

- 1 _____
- 2 _____
- 3 _____

Q17 How many times per day do you feed your dog's **primary food**? (Snacks and treats not included)

- ○ Once
- ○ Twice
- ○ Three times
- ○ Four times
- ○ Free feed (constant access)

Q18 When your dog is offered food, does s/he:

- ○ Complete the meal immediately
- ○ Complete the meal within one hour
- ○ Eat small portions but complete within 2 hours
- ○ Always leave something in the bowl

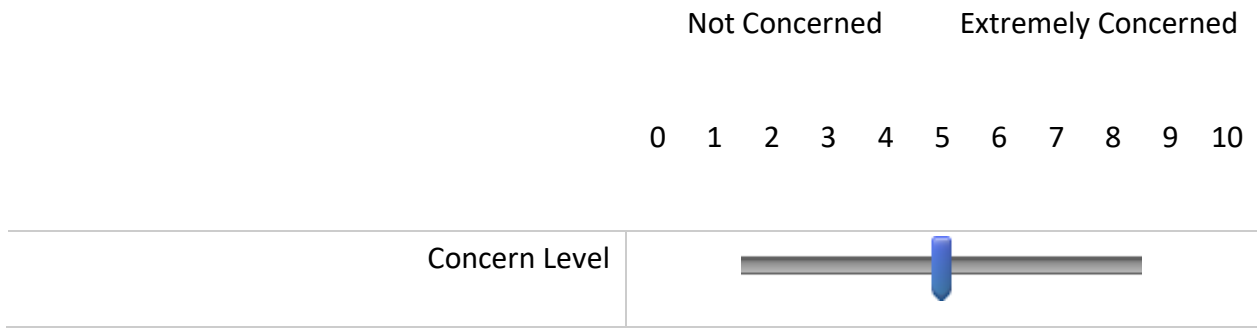
Q19 How do you decide the amount of food given to your dog per feeding?

- ○ Feeding guidelines found on the package label
- ○ Veterinarian recommendation
- ○ Decide based on animal cues (begging, signs of hunger, etc.)
- ○ Decide based on animal body condition or weight
- ○ Decide on how much feels just about right

Q20 Please specify the amount of food you give your dog per feeding. Feel free to use **EITHER** grams or ounces, which ever you feel more comfortable with. If you are uncertain, it is ok to provide a ballpark estimate.

- ○ Amount in Grams _____
- ○ OR Amount in Ounces _____

Q21 Please indicate your level of concern for obesity in your dog. (0= not concerned, 10= extremely concerned)



Dog Treats

Please tell us a little more about the treats you give your dog.

Q21 How often do you give your dog **treats**?

- ○ Never
- ○ Only on special occasions (Less than one time a day)
- ○ Once a day
- ○ Twice a day
- ○ Three times a day
- ○ Four times a day
- ○ 5 or more times a day

Q22 What type of **treat** do you normally offer to your dog? (Select all that apply)

- ○ Crunchy treats
- ○ Soft-moist treats
- ○ Jerky
- ○ Dental treats
- ○ Animal parts (bones, hooves, ears, pizzles, etc.)
- ○ Rawhides
- ○ Table scraps
- ○ Other _____

Q23 Please type the brand name of your dog's **treats** in the text boxes below. Please specify the top three brands used from (1) most frequently used to (3) least frequently used. For each brand, please specify the product name and the treat size. (e.g., Purina, Busy Bone, Medium)

If your dog's treats are home prepared, please specify in the formulation/recipe text box the main ingredients used in your dog's treats from (1) most frequently used to (3) least frequently used. (e.g., raw chicken, grains, etc.)

	Brand Name	Product Name	Treat Size
1			
2			
3			

Q24 Please specify the amount of treats you give your dog per occasion. Feel free to use EITHER units (e.g., 2 pieces) or grams or ounces, which ever you feel more comfortable with. If you are uncertain, it is ok to provide a ballpark estimate.

- ○ Amount in units (pieces) _____
- ○ OR Amount in Grams _____
- ○ OR Amount in Ounces _____

Q25 Do you adjust the amount of primary food given to your dog based on the amount of treats provided during the day?

- ○ Yes
- ○ No

Dog Behavior / Cues

Now, please tell us about your dog's behavior.

Q26 Please indicate how often your dog does the following when waiting for food/treats.

	Always	Often	Sometimes	Rarely	Never
whines/barks	○	○	○	○	○
wags his/her tail	○	○	○	○	○
gazes/stares at you	○	○	○	○	○
moves around and jumps in excitement	○	○	○	○	○
licks his/her mouth	○	○	○	○	○
sits and waits in excitement	○	○	○	○	○
gazes/stares at the place(s) where food/treats are stored	○	○	○	○	○

Q27 Please indicate how often your dog does the following when eating food/treats

	Always	Often	Sometimes	Rarely	Never
shows aggressive behavior toward a person or pet in close proximity	○	○	○	○	○
guards the food	○	○	○	○	○
eats faster when a person or pet is in close proximity	○	○	○	○	○
snarls	○	○	○	○	○

Dog Exercise

Now, please tell us about your dog's level of physical activity.

Q28 First, let's think about your dog's **low intensity** activities (e.g., walk). Please specify below the number of times per week that your dog participates in a **low intensity** activity and the duration per occasion.

# of times per week	
duration per time/activity (in minutes)	

Q29 Next, let's think about your dog's **medium intensity** activities (e.g., play fetch or other organized activity). Please specify below the number of times per week that your dog participates in a **medium intensity** activity and the duration per occasion.

# of times per week	
duration per time/activity (in minutes)	

Q30 Now, let's think about your dog's **high intensity** activities (e.g., run, jog). Please specify below the number of times per week that your dog participates in a **high intensity** activity and the duration per occasion.

# of times per week	
duration per time/activity (in minutes)	

End of Survey

Your response has been recorded.

Thank you for your time and valuable information.
We wish you and your pet well!

Appendix D - Pet Weight Deviation Estimation Results by Breed

Appendix D - Table 5.3. Pet Weight Deviation Parameter Estimate Results by Breed

Variable	Toy Breed	Small Breed	Medium Breed	Large Breed	Giant Breed
Caloric Intake Parameter Estimates					
total calories	0.008 (0.000)	**0.003*** (0.000)	**0.002***** (0.000)	**0.001***** (0.000)	0.002 (0.001)
feed frequency	**-0.336*** (0.176)	**-0.073*** (0.042)	**-0.063**** (0.031)	**-0.068***** (0.021)	-0.072 (0.108)
feed type	0.248 (0.375)	**-0.150**** (0.066)	-0.109 (0.090)	**-0.093**** (0.047)	**-0.342**** (0.160)
treat frequency	**0.108*** (0.059)	0.015 (0.014)	0.011 (0.010)	-0.004 (0.007)	0.018 (0.029)
treat calorie percentage	**-0.967*** (0.494)	-0.198 (0.135)	-0.127 (0.096)	-0.029 (0.085)	0.838 (0.657)
feeding based on weight (fbw)	0.106 (0.277)	-0.030 (0.101)	**0.113*** (0.059)	0.083 (0.055)	0.184 (0.173)
feeding based on vet recommendation (fbv)	0.113 (0.499)	**-0.194*** (0.108)	0.156 (0.104)	0.079 (0.070)	0.168 (0.233)
total calories * fbw	-0.0004 (0.007)	-0.0004 (0.002)	**-0.001*** (0.000)	**-0.0008*** (0.000)	-0.002 (0.001)
total calories * fbv	0.005 (0.009)	**0.006***** (0.002)	0.0006 (0.001)	0.0004 (0.000)	-0.001 (0.001)
Caloric Output Parameter Estimates					
low exercise	0.0005 (0.0006)	**0.0002**** (0.0001)	0.0009 (0.0005)	-0.0005 (0.0006)	-0.0008 (0.0001)
medium exercise	-0.0003 (0.002)	-0.0008 (0.002)	-0.0006 (0.001)	0.0001 (0.0008)	0.0007 (0.0004)
high exercise	0.001 (0.001)	-0.0004 (0.002)	0.0015 (0.0011)	-0.0001 (0.0007)	0.0002 (0.0005)

Appendix D – Table 5-3. Pet Weight Deviation Estimation Results (cont.)

Variable	Toy Breed	Small Breed	Medium Breed	Large Breed	Giant Breed
Genetic Pre-disposition Parameter Estimates					
dog intact	0.141 (0.475)	-0.087 (0.089)	-0.088 (0.057)	0.034 (0.038)	-0.083 (0.120)
dog sex	**-0.271*** (0.157)	**-0.134***** (0.050)	**-0.122***** (0.032)	**-0.055**** (0.022)	-0.028 (0.082)
dog age (months)	0.0004 (0.002)	0.0004 (0.0005)	0.0006 (0.0004)	**0.001***** (0.000)	-0.0003 (0.001)
constant	0.701 (0.435)	0.031 (0.109)	-0.038 (0.085)	**-0.225***** 0.064	-0.322 (0.219)
Observations	100	217	378	432	41
F-Statistic	1.12	8.91	5.04	4.93	19.70
Prob > F	0.3504	0.0000	0.0000	0.0000	0.0000
R-squared	0.2794	0.2008	0.1581	0.1344	0.3963
Root MSE	0.8594	0.3707	0.3085	0.2318	0.1940

Notes: Elasticities are evaluated at the sample mean values. Standard errors are in parenthesis.:

*** p < 0.01; ** p < 0.05; * p < 0.10

Appendix E - Summary of 46 U.S. Pet Dog Markets

Appendix E -Table 5.4. Average Price of Animal-based Protein Dog Foods in 46 U.S. Retail Markets from 2017-2020

Retail Market	Region	Beef	Lamb	Chicken	Turkey	Salmon
Atlanta, GA	3	2.04	2.25	2.55	2.93	2.21
Baltimore/Wash, MD-DC	3	2.46	2.48	2.78	3.68	2.68
Birmingham, AL	3	1.42	1.80	2.04	2.24	2.18
Buffalo/Rochester, NY	2	3.00	2.96	2.66	3.31	4.70
Charlotte, NC	3	1.84	2.30	2.31	2.65	2.28
Chicago, IL	1	2.33	4.68	2.93	3.10	2.74
Cincinnati, OH	1	1.76	2.22	2.42	2.84	2.17
Cleveland, OH	1	1.88	2.19	3.34	8.67	2.24
Columbus, OH	1	1.66	1.85	2.51	2.63	2.93
Dallas, TX	3	1.98	2.52	2.41	3.15	2.25
Denver, CO	4	2.05	2.25	2.57	8.00	2.62
Detroit, MI	1	2.03	2.13	2.82	2.68	2.04
Harrisburg, PA	2	1.90	2.23	2.56	2.58	2.62
Hartford/Springfield, MA	2	2.74	2.21	2.95	3.14	2.50
Houston, TX	3	1.68	1.92	2.36	3.04	1.96
Indianapolis, IN	1	1.53	1.93	2.24	2.87	1.99
Kansas City, KS	1	1.75	1.95	2.18	2.44	2.00

Appendix E -Table 5-4. Average Price of Animal-based Protein Dog Foods in 46 U.S. Retail Markets from 2017-2020 (cont.)

Retail Market	Region	Beef	Lamb	Chicken	Turkey	Salmon
Los Angeles, CA	4	1.99	3.25	2.51	5.57	2.51
Louisville, KY	3	2.15	2.11	2.67	3.37	2.14
Miami, FL	3	2.26	2.47	3.06	3.03	2.58
Milwaukee, WI	1	2.55	3.08	2.70	3.54	2.22
Minneapolis, MN	1	2.39	3.40	3.26	2.87	2.55
Nashville, TN	3	1.52	1.63	2.42	1.94	2.22
New England, MA	2	1.69	1.97	2.27	2.50	2.24
New Orleans, LA	3	1.67	2.30	2.14	2.63	2.00
New York, NY	2	2.73	3.18	3.37	3.51	3.20
Oklahoma City, OK	3	1.50	1.66	1.81	1.89	1.65
Orlando, FL	3	1.92	1.98	2.51	2.98	2.31
Peoria/Springfield, IL	1	1.54	1.65	2.08	2.05	1.76
Philadelphia, PA	2	2.09	2.48	2.67	3.79	2.36
Phoenix, AZ	4	1.90	2.17	2.59	4.38	2.07
Pittsburgh, PA	2	1.78	1.89	2.56	3.12	2.44
Portland, OR	4	2.21	2.29	2.70	4.39	1.72
Raleigh/Greensboro, NC	3	1.84	2.18	2.37	2.75	2.24
Richmond, VA	3	2.07	2.07	2.49	2.35	2.27

Appendix E - Table 5-4. Average Price of Animal-based Protein Dog Foods in 46 U.S. Retail Markets from 2017-2020 (cont.)

Retail Market	Region	Beef	Lamb	Chicken	Turkey	Salmon
Roanoke, VA	3	1.38	1.48	1.97	1.92	2.30
Sacramento, CA	4	2.20	2.79	2.43	3.03	2.75
San Antonia/Corpus Christi, TX	3	1.67	1.66	2.15	2.67	1.41
San Diego, CA	4	2.12	2.31	2.72	2.37	2.50
San Francisco, CA	4	2.66	3.16	2.99	10.38	2.56
Seattle, WA	4	2.26	3.75	2.88	3.29	2.45
South Carolina	3	1.61	2.20	2.32	2.54	2.61
St. Louis, MO	1	1.65	2.03	2.18	2.36	1.68
Tampa, FL	3	2.00	2.15	2.62	3.54	2.49
Toledo, OH	1	1.81	2.10	2.06	2.45	2.36
West Texas / New Mexico	4	1.70	2.18	2.28	2.24	1.94