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YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS
PhD PROGRAM IN ECONOMICS

PhD DISSERTATION

THREE ESSAYS IN BIOECONOMICS

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THESIS ADVISOR
PROF. DR. HÜSEYİN TAŞTAN

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Volkan Güngör tarafından hazırlanan “Three Essays in Bioeconomics” başlıklı çalışma, **24/03/2025** tarihinde yapılan savunma sınavı sonucunda oybirliği ile başarılı bulunmuş ve jürimiz tarafından İktisat Ana Bilim Dalı İngilizce İktisat Programında **DOKTORA** tezi olarak kabul edilmiştir.

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Prof. Dr. Murat Donduran	……

ABSTRACT

THREE ESSAYS IN BIOECONOMICS

This dissertation presents three studies of empirical bioeconomics focusing on Turkish large-scale marine fisheries and their interactions with the market. The first essay aims to assess the supply side of marine fisheries. By using Turkish Statistical Institute Fisheries Micro Data Set (2015-2021) and constructing a generalized fishery model, the logistic growth function, including intrinsic growth rate, carrying capacity, and monthly average stock levels, and the harvest function, including catchability and effort elasticity, are estimated. Then, the obtained stock estimates are used to estimate a stochastic frontier for harvest and factors of inefficiency. The findings illustrate that variations in harvest are primarily caused by stock level fluctuations, rather than fishing effort. It is also found that the fisheries are operating below the maximum sustainable yield (MSY) due to previous exploitation. Although the findings reveal that unit characteristics determine the efficiency of individual fisheries, the aggregate efficiency is found to be influenced by the trends in biomass levels.

The second essay seeks to evaluate the demand for seafood in Turkey. A multi-stage budgeting approach is employed, incorporating censored dependent variables, endogeneity, and demographic scaling, utilizing the TurkStat Household Budget Survey 2003 dataset. This study addresses consumption-savings behavior to eliminate the endogeneity issue often overlooked in the literature. Moreover, it introduces a novel approach by integrating demographic scaling with the consideration of censored dependent variables inside systems of demand equations. The results demonstrate that seafood consumption is regarded as a luxury good and less responsive to price fluctuations. Additionally, greater elasticities are found among the households with larger restaurant, tobacco, and alcohol expenditures.

The third essay aims to construct a bioeconomic model of Turkish large-scale fisheries within the context of the present fisheries strategy. For this purpose, the Turkish regulatory framework is categorized under a classification of fisheries regimes. Subsequently, utilizing the parameters outlined in preceding sections and additional data acquired from the TurkStat Central Dissemination System, a discrete dynamic programming approach is implemented across various season lengths, fishing capacities, and market shares of fish meal and fish oil (FMFO) factories. The results indicate that attaining maximum sustainable yield (MSY) levels necessitates a substantial decrease in fishing capacity by about 33% and a reduction in season length by 2 months. Furthermore, these measures are illustrated as to produce a net welfare gain attributable to consumer surplus, notwithstanding the decline in fishing profitability. Lastly, it is explained that regulations reducing the market power of FMFO factories and middlemen may reduce the losses in fisher welfare.

Keywords: Fisheries Regulation, Technical Inefficiency, Seafood Demand, Bioeconomic Modeling

ÖZET

BİYOİKTİSAT ÜZERİNE ÜÇ MAKALE

Bu tez, Türkiye'deki büyük ölçekli deniz balıkçılığına ve bunların piyasayla etkileşimlerine odaklanan üç ampirik biyoekonomik analiz sunmaktadır. İlk makale, deniz balıkçılığının arz tarafını değerlendirmeyi amaçlamaktadır. Türkiye İstatistik Kurumu Su Ürünleri Mikro Veri Seti (2015-2021) kullanılarak ve genelleştirilmiş bir balıkçılık modeli oluşturularak, içsel büyüme oranı, taşıma kapasitesi ve aylık ortalama stok seviyelerini içeren lojistik büyüme fonksiyonunu ve yakalanabilirlik ve çaba esnekliğini içeren hasat fonksiyonu tahmin edilmektedir. Daha sonra, elde edilen stok tahminleri, hasat ve verimsizlik faktörleri için stokastik sınırın tahmini için kullanılır. Bulgular, hasattaki değişikliklerin balıkçılık çabasından ziyade öncelikle stok seviyesi dalgalanmalarından kaynaklandığını göstermektedir. Ayrıca, balıkçılığın önceki kullanım nedeniyle maksimum sürdürülebilir verimin (MSY) altında faaliyet gösterdiği de bulunmuştur. Bulgular, birim özelliklerinin bireysel balıkçılığın verimliliğini belirlediğini ortaya koysa da toplam verimliliğin biyokütle seviyelerindeki eğilimlerden etkilendiği bulunmuştur.

İkinci makale, Türkiye'deki deniz ürünlerine olan talebi değerlendirmeyi amaçlamaktadır. Sansürlü bağımlı değişkenler, içsellik ve demografik ölçeklemeyi içeren çok aşamalı bir bütçeleme yaklaşımından, TÜİK Hanehalkı Bütçe Anketi 2003 veri setini kullanarak faydalanılmaktadır. Bu çalışma, literatürde sıklıkla göz ardı edilen içsellik sorununu ortadan kaldırmak için tüketim-tasarruf davranışını ele almaktadır. Buna ek olarak, talep denklemleri sistemleri içindeki sansürlü bağımlı değişkenlerin dikkate alınmasıyla demografik ölçeklemeyi entegre ederek yeni bir yaklaşım sunmaktadır. Sonuçlar, deniz ürünlerinin lüks bir mal olarak kabul edildiğini ve fiyat dalgalanmalarına daha az duyarlı olduğunu göstermektedir. Ek olarak, daha fazla restoran, tütün ve alkol harcamalarına sahip haneler arasında daha yüksek esneklikler bulunmaktadır.

Üçüncü makale, mevcut balıkçılık stratejisi bağlamında Türk büyük ölçekli balıkçılığının biyoekonomik bir modelini oluşturmayı amaçlamaktadır. Bu amaçla, Türk düzenleyici çerçevesi bir balıkçılık rejimleri sınıflandırması altında kategorize edilmiştir. Daha sonra, önceki bölümlerde özetlenen parametreler ve TÜİK Merkezi Dağıtım Sistemi'nden edinilen ek veriler kullanılarak, çeşitli sezon uzunlukları, balıkçılık kapasiteleri ve balık unu ve balık yağı (FMFO) fabrikalarının pazar payları arasında ayrık dinamik programlama yaklaşımı uygulanmıştır. Sonuçlar, maksimum sürdürülebilir hasat (MSY) seviyelerine ulaşmanın balıkçılık kapasitesinde yaklaşık %33 oranında önemli bir azalma ve sezon uzunluğunda 2 aylık kısaltma gerektirdiğini göstermektedir. Dahası, bu önlemlerin balıkçılık karlılığındaki düşüşe rağmen tüketici fazlasına atfedilebilen net bir refah kazanımı getirdiği gösterilmiştir. Son olarak, FMFO fabrikalarının ve aracıların pazar gücünü azaltan düzenlemelerin balıkçı refahındaki kayıpları azaltabileceği açıklanmıştır.

Anahtar Kelimeler: Balıkçılık Düzenlemesi, Teknik Verimsizlik, Deniz Ürünleri Talebi, Biyoekonomik Modelleme

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ABBREVIATIONS

AIDS	: Almost Ideal Demand System
CFP	: Common Fisheries Policy
CMSY	: Catch Maximum Sustainable Yield
CPUE	: Catch Per Unit Effort
DEA	: Data Envelopment Analysis
EU	: European Union
FAO	: Food and Agricultural Organization
FMFO	: Fish Meal and Fish Oil
GWMP	: Geometrically Weighted Mean of Price
GTL	: Generalized Translog
HBS	: Household Budget Survey
HW	: Heien and Wessels
IMR	: Inverse Mill's Ratio
IPHC	: International Pacific Halibut Commission
ITL	: Indirect Translog
ITQ	: Individual Transferable Quota
JLMS	: Jondrow, Lovell, Materov, Schmidt
LA/AIDS	: Linearly Approximated Almost Ideal Demand System
LES	: Linear Expenditure System
LP	: Laspeyres
MEDAS	: Merkezi Dağıtım Sistemi
MEY	: Maximum Economic Yield
MRS	: Marginal Rate of Substitution
MSY	: Maximum Sustainable Yield
NLS	: Nonlinear Least Squares
NUTS	: Nomenclature of Units for Territorial Statistics
OECD	: Organization for Economic Co-operation and Development
OLS	: Ordinary Least Squares
PIGLOG	: Price Independent Generalized Logarithmic
QUAIDS	: Quadratic Almost Ideal Demand System
ROA	: Regulated Open Access
RRA	: Regulated Restricted Access
RTA	: Restaurant, Tobacco, Alcohol
RTC	: Real Time Closures
SFA	: Stochastic Frontier Analysis
SY	: Shonkwiler and Yen
TAC	: Total Allowable Catch
TCKB	: Türkiye Cumhuriyeti Kalkınma Bakanlığı
TE	: Technical Efficiency
TE	: Total Expenditures
TEPGE	: Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü Müdürlüğü
TFE	: Total Food Expenditures
TL	: Transcendental Logarithmic
TOB	: Tarım ve Orman Bakanlığı

TurkStat : Turkish Statistical Institute
VMS : Vessel Monitoring System

1 INTRODUCTION

The capture fisheries and aquaculture sectors play pivotal roles in global food security, employment, and economic development, particularly in coastal regions. This is mainly driven by the recent expansion of aquaculture, which is the fastest-growing food sector worldwide (Troell et al., 2014). Meanwhile, capture fisheries' harvest levels have stagnated over the last decades (FAO, 2022). The reductions in wildlife stocks and loss of habitats affected by the impacts of climate change (IPCC, 2023), pollution (UNEP, 2009), and overfishing (Srinivasan et al., 2010) are considered the main reasons for this trend.

The oceans absorb the majority of the excess energy caused by rising global temperatures that refer to climate change. The resulting ocean warming is associated with several environmental changes, including more intense rainfall, rising sea levels, coral reef degradation, declining ocean oxygen levels, and melting polar ice sheets. These environmental changes significantly threaten marine life and global food security. A recent climate risk index on marine species illustrates that more than half of marine species will be at least at high risk by 2100, even under the low-emission scenario, and low-income nations that rely on fisheries and have lower historical emissions will be influenced the most (Boyce et al., 2022).

Some of the sources of marine pollution arising from human activities can be listed as offshore oil and gas searching and extraction activities, aquaculture installations and processes, and all activities employing marine vehicles for trade, transport, tourism, research, national defense, and fishing, as well as untreated land-based waste from municipalities, industrial facilities, and coastal touristic activities. In addition to glass, plastic, metal, and other material items heavily found in the seabed, ghost-fishing that occurs due to abandoned, discarded, or lost fishing nets disturbingly threatens marine life (UNEP, 2009).

Overfishing is arguably the most significant problem responsible for melting stocks. In fisheries management terms, this problem can be associated with fishing effort,

which refers to fishing vessels' technical and technological properties and the duration of fishing activities. Over the years, probably due to developments in fisheries technologies and the profitable nature of industrial fishing activities, along with increased consumer and input demand, empirical studies show that fishing capacity and effort worldwide have steadily increased, although the global catch has remained relatively constant (Anticamara et al., 2011; Bell et al., 2017). As a result, there has been an approximate annual increase in global catch losses of about 0.25 million tonnes due to overfishing (Srinivasan et al., 2010).

Located on a peninsula, the Black Sea surrounds Turkey to the north, the Aegean Sea to the west, and the Levantine Sea to the south. Entirely circled by the country's coasts, the Marmara Sea connects the Aegean Sea to the Black Sea through the Dardanelles and the Bosporus. Ulman et al. (2013) provide a summary of Turkey's marine fishing history covering these four major marine regions. Since the 1930s, the national catch quantity has increased, with species such as bonito and Atlantic mackerel commonly fished during this time. Turkey's fishing industry has grown rapidly since the early 1950s, with improved industrial practices and technological advancements. However, this progress has resulted in overfishing and environmental degradation. Significant decreases in fish stocks caused by overfishing and ecological imbalances necessitated the implementation of new management and conservation strategies, particularly in the Black Sea, by the late 1980s. The transition to a market-based economy in the 1980s and increased government investment in the fishing sector have resulted in major transformations in Turkish fishing activities. This was a period of significant increases in anchovy fishing, making it a vital industry of the national economy. As a result of the decline in demersal fisheries due to overfishing, some bottom trawl vessels began targeting small pelagic species in the 1990s. Overall, associated with changes in fishing methods and technology, Turkey's maritime fishing species composition has changed dramatically between 1950 and 2010, shifting from larger, more valuable fish to smaller, less valuable ones.

Today, the Ministry of Agriculture and Forestry (TOB) is responsible for fisheries management in Turkey under Law 1380 (1971). The regulations for commercial fisheries enforced by the Ministry via Circular No. 5/1 (Resmi Gazete, 2020) are generally associated with overcapacity and resource conservation issues. Several restrictions, prohibitions, and responsibilities are currently enforced on commercial

fisheries. Many apply exclusively to specific fishing methods, zones, species, and other requirements. To illustrate, all types of trawl fishing are banned in Turkey's internal waters, including the Marmara Sea, the Bosporus and Dardanelles, and specified zones within the Levantine, Aegean, and Black Seas. They are also limited by minimum mesh size, period, and other technical requirements, unless they are not entirely prohibited in many regions. In addition, beam trawls and dredges are also strictly regulated with bans in certain areas, restrictions on the size of nets and gear dimensions, and the requirement for fishing permits as they are widely used in mollusk and sea snail fishing. Finally, relatively tight but similar restrictions are also observed in the use of purse seines. Furthermore, the regulations express prohibitions on the capture of certain species, such as sea turtles (Caretta caretta), and enforce minimum size and weight standards for commercially valuable fish species; for example, harvested anchovy (Engraulis encrasicolus) must be at least 9 cm long.

Recently, in Circular No. 6/1 (Resmi Gazete, 2024), the first significant attempt at output controls in addition to previous regulations, has started for anchovy by assigning individual nontransferable quotas to a limited number of vessels. However, as the total quota exceeds even the historical peak levels, this policy cannot be considered effective. Another regulation related to anchovy catches is a limitation on their sales to fish meal and fish oil (FMFO) factories. Accordingly, at most 50% of anchovy catches may be sold to them, except in the Marmara Sea, where bulk sales to these facilities are prohibited.

The penalties for non-compliance with legal regulations include administrative fines, transferring the related private property and proceeds of crime to public ownership, and imprisonment for repeated violations. In addition, in accordance with the November 2019 amendment to the Law, individuals and entities that wish to participate in commercial fishing activities and those using vessels for similar reasons must obtain a license certificate or permit from the TOB. Although these regulations are highly comprehensive and promising, their practical applicability is questionable. For example, Ulman et al. (2013) claim that although bottom trawling was prohibited in 1971, illegal fishing has continued as lawbreakers were difficult to catch. In fact, they estimated that the total amount of unreported catch and discard levels was around half of the reported catch levels even in 2010. In addition, these regulations do not directly mention the possible drawbacks of technological developments.

In addition to the legal background, the development plans and sector reports can provide valuable insights into fisheries management in Turkey. The Special Commission Report for the 10th Development Plan summarizes the developments in the previous period (TCKB, 2014). Particular focus is observed on institutional structure, resource management and conservation, enhancements of data collection infrastructure, and restoration of infrastructure such as fishing harbors. To begin with, during the 2007-2013 period, the General Directorate of Fisheries and Aquaculture (BSGM) was established under the Ministry. The start of the annual fishing ban was rescheduled from May 1 to April 15, and the minimum fishing lengths of certain species were increased. The depth limit from the shore for purse seine fishing was increased to 24 meters. The number of marine protected areas was increased and extended in certain regions. Notable advancements have been made in establishing the required infrastructure and institutional capability to align with the Common Fisheries Policy (CFP) of the European Union (EU).

During this period, there had been a notable increase in subsidies allocated to aquaculture. In contrast, financial assistance provided to fishermen had been restricted to reduced fuel prices and loans to decrease their expenses and seafood prices. The maximum number of vessels employed in fishing activities was recorded in 2003, totaling 18542 fishing units. Subsequently, the number of fishermen declined and reached its minimum level of 13727 in 2013. In 2012, the first buy-back program was introduced for vessels larger than 12 meters, providing nominal payments to vessel owners wishing to retire their vessels from fishing.

The Fisheries Sector Policy Document takes a similar approach (TOB, 2019). In 2017, the scope of support was extended to cover small-scale fishing units that employ conventional fishing techniques. Still, the number of small-scale fishing units has slightly decreased since then. The total number of vessels has been stable between 14000 and 14500 since 2014. Information relating to the fishing activities and socio-economic conditions of fishers operating in marine and freshwater environments was documented, and financial assistance was provided. Since 2014, collaborative efforts between the Ministry and TurkStat have been undertaken to conduct monthly surveys to gather relevant information on marine fisheries. In 2016, the Vessel Monitoring System (VMS) was constructed to control fishing operations of fishing vessels with a length of 12 meters or more and to gather pertinent information on fishing activities in

the seas. The VMS program employs GSM and satellite technology to monitor the fishing operations of 1500 vessels. The collection of fishing data from fishing vessels started by using electronic logbooks. Environmental monitoring activities were conducted to monitor the status of pollution, as well as oceanographic and limnological data in seas and lakes. Research activities have been undertaken to modify fishing gears with adverse environmental impacts in fisheries or to adapt novel fishing gears utilized in global fishing practices to the Turkish context. The introduction and advancement of innovative fishing technologies, such as midwater trawl and shrimp separators, have facilitated this.

The technical assistance cooperation "Initiation of Stock Assessment in the Turkish Fisheries System" has been implemented to enhance the institutes' infrastructure within the International Pacific Halibut Commission (IPHC). In 2014, the Ministry initiated the "Project for Cleaning the Seas from Abandoned Fishing Gears", utilizing only public funds. This project aimed to mitigate ghost fishing in Turkey's seas by removing abandoned fishing gear during fishing activities. The project also seeks to minimize the economic impact of lost fishing gear on sea products and safeguard the ecosystem and resources.

The increase in the number of fishing vessels in the fleet was intended to be stopped, and four buy-back programs were implemented between 2012 and 2018. In these programs, 1264 fishing vessels with a length greater than 10 meters were removed from the fleet. According to Göktay et al. (2018), the first program excluded 364 vessels that exceeded a length of 12 meters, with the majority falling below 20 meters. According to the survey conducted, it was found that 17% of the owners who joined the program expressed their intention to purchase a new vessel, whereas 45% already had a second one and chose to sell the less profitable or idle vessels. Then, Ekmekci & Ünal (2019) illustrate that the second program involved the removal of 446 vessels that exceeded a length of 10 meters, while 440 vessels were found to be below 20 meters. Around 27% of the 207 owners who participated in the survey expressed their intention to purchase a new one, while 28% determined to sell their unprofitable or idle secondary vessels. Next, for Ünal & Göncüoglu-Bodur (2020a), the third program removed 191 vessels, all of which were above 10 meters, and the majority were below 12 meters. Out of the 89 owners surveyed, 26% intended to purchase a new vessel, while 60% decided to sell their secondary vessels that were not profitable or in use.

Finally, Ünal & Göncüoglu-Bodur (2020b) surveyed 52 owners out of 213. They found that 78% intended to purchase a new vessel, while 13% removed their idle second vessels. Based on data provided by the TurkStat, there has been a decline in the number of fishing vessels with 10-20 meters in length. Specifically, the number of such vessels decreased from 1709 in 2012, when the initial program was introduced, to 1387 by 2018, when the final program was concluded, representing a reduction of 322. However, this was considerably insufficient compared to the overall 1166 vessels that participated in the programs. Although only 48 of the larger vessels were involved in the program, their numbers experienced a decline of 144. However, asserting that the programs accomplished their intended goals is not feasible. Furthermore, since many vessels involved in the buyback programs were idle or inefficient, renewed vessels have resulted in a fleet characterized by increased capacity and enhanced fishing effort compared to its previous state.

Turkey's developments in the share of its seafood production originating from capture fisheries and aquaculture have reflected global trends. More critically, output from capture fisheries has declined over the past three decades, whereas the production from aquaculture has expanded (FAO, 2021). This decline is primarily due to the dramatic deterioration of fish stocks resulting from overfishing. As a result, the economic value of capture activities has decreased over the same period due to production losses and rising costs. Furthermore, the expansion of marine aquaculture activities might be claimed to deepen the problems of marine pollution and overfishing arising from the increasing input demand for the captured seafood to be used as feed in the aquaculture industry.

Moreover, despite Turkey's extensive coastline and plentiful water resources, and the growth of aquaculture output with government subsidies, seafood intake in the country is much lower than that of other protein sources and the global average. The supply of seafood for domestic consumption is often limited by growing exports and large purchases by fish meal and fish oil facilities. While the increase in aquaculture enhances seafood output, a significant portion is exported instead of being consumed domestically, especially species such as seabream, seabass, and trout. The seafood trade balance in Turkey is positive, excluding imports of fishmeal and fish oil, underscoring the impact of aquaculture feed demand on seafood supply.

The contribution of bioeconomics and associated data analysis to the literature on Turkish fisheries management is minimal, with the economic dimensions of fisheries policy mainly consisting of assertions found in policy papers. This is not due to the lack of attention by economists to the issue but due to their approaches. Early studies have defined the issue as a local management to commons problem (Berkes, 1986; Ostrom, 1990). Some analyses have approached the issue from a historical perspective, providing valuable insights about the history and development of the Turkish fisheries and policy from the early Republican period to recent decades (Knudsen, 2004), even informing about levels of discards and illegal fishing activities (Ulman et al., 2013). Moreover, there have been studies that have made use of qualitative data collected from several agents in the sector, portraying the current conditions from a perspective of political economy and individual perceptions of the agents from the fisheries and aquaculture industry (Ertör & Ortega-Cerdà, 2019).

In recent years, the supply side of the sector has been analyzed by a series of technical efficiency analyses based on primary survey datasets (Ceyhan & Gene, 2014; Dağtekin et al., 2021, 2022; Tunca et al., 2021). Moreover, there have been studies using price and landings data to evaluate the market conditions (Yildiz et al., 2023) and fisheries management strategies (Demirel et al., 2023; Yıldız et al., 2020). Next, by exploiting time-series information of price information, Bayramoglu (2019) has analyzed the price interactions between wild and farmed products. Finally, the first large-scale stock assessment in Turkish fisheries was conducted by Demirel et al. (2020) using long time series of regional catch data for several species.

Overall, current global trends in seafood production indicate a slowdown in catch fisheries and a rapid increase in aquaculture, a pattern also observed in Turkey. This alteration is primarily attributed to declining wild fish populations resulting from overfishing, pollution, and climate change. Ocean warming and marine pollution, stemming from industrial activity, discarded fishing gear, and unregulated coastal practices, present further concerns to marine biodiversity and food security. Despite Turkey's abundant maritime geography and long-term fishing culture, resource overexploitation has resulted in ecological deterioration and a transition in catch composition from high-value to low-value species.

In response to these developments, Turkish fisheries management has implemented numerous regulatory and institutional reforms, including seasonal fishing prohibitions,

size and gear limitations, vessel monitoring systems, and buy-back programs aimed at mitigating fleet overcapacity. Nonetheless, obstacles in implementation and efficacy persist, particularly in mitigating the unintended repercussions of illegal fishing and technology advancements.

Despite extensive academic literature and regulatory advancements stemming from a longstanding fishing heritage, the economic analysis of Turkish fisheries is still limited. The majority of current literature relies on historical, qualitative, or policy-oriented methodologies, whereas new research has started to investigate productivity, market dynamics, and stock assessments through quantitative techniques. A comprehensive bioeconomic analysis that incorporates production, consumption, and market behavior within a sustainability framework is currently absent.

The three essays in this dissertation are one of the initial attempts to draw a bioeconomic portrait of Turkish fisheries and its policy implications by aiming on production processes, consumption and usage behaviors, and their interactions in the market in line with the considerations of resource conservation and social welfare. While the first and second studies are based on the data sets obtained from the TurkStat, the third study benefits from the parameters obtained in the initial sections.

The first essay evaluates the supply side of the marine fisheries in Turkey. Considering the persistent concerns of overexploitation, declining economic outcomes, and limited bioeconomic analysis in the literature, this study addresses several interconnected research issues. To begin with, without some knowledge about the biomass level in Turkish territorial waters, a comprehensive understanding of how fisheries policy can mitigate overfishing is uncertain. Thus, the interactions between short-term stock dynamics and associated fishing activities should be revealed based on an available data set. Next, based on the current stock and effort levels, how regional and technological factors can affect the exploitation of resources should be examined to formulate a more effective fisheries policy.

In order to propose solutions to these issues, the first essay estimates bioeconomic parameters, harvest function, and the determinants of technical inefficiency in Turkish large-scale marine fisheries, using the TurkStat Fisheries Micro Data Set (2015-2021). The bioeconomic parameters include intrinsic growth rate and carrying capacity of the logistic growth function which also allows for estimates of monthly average stock levels. Moreover, the Cobb-Douglas harvest function includes catchability coefficient,

effort elasticity, and stock elasticity. Finally, the technical, technological, and regional characteristics that fishing units exhibit are considered inefficiency effects. To obtain those estimates, first, a generalized fishery model proposed by Zhang & Smith (2011) is utilized. Then, using the stock estimates, a stochastic frontier model with inefficiency effects is estimated by the method suggested by Battese & Coelli (1995). To the best of the author's knowledge, this is the first comprehensive panel data analysis of Turkish fisheries using the TurkStat Fisheries Micro Data Set.

The study finds that stock level fluctuations are the primary factor driving fluctuations in harvest levels, rather than fishing efforts. It is also evident that the fisheries operate below the maximum sustainable yield (MSY) due to previous exploitation. The results also illustrate that although individual fisheries efficiency is determined by unit characteristics, overall efficiency follows the trends in the biomass levels.

The second essay aims to assess the seafood demand in Turkey. In spite of its wide-ranging shoreline and abundant resources, Turkish seafood intake is relatively low. This study seeks to clarify the association between specific socioeconomic characteristics and poor seafood demand in a coastal country. A multi-stage budgeting approach, based on a utility tree by which the households gradually allocate their income into group and subgroup expenditures, is utilized. The model accounts for censored dependent variables, endogeneity, and demographic scaling, using the TurkStat Household Budget Survey 2003 (HBS2003) dataset.

As the dataset contains large numbers of zero consumption levels for different food groups, especially seafood, the dependent variables in the system of expenditure-share equations are highly censored, leading to severe observation losses. Although this might occur due to simple taste and preferences, it is highly possible that alternative timing of surveys or sampling might lead to a series of recoveries in these observations and ignoring them leads to a sample selection bias. In other words, if those observation losses are neglected, the analysis is conducted only among seafood consumers by a self-selected sample. Thus, by employing a series of probit estimations using many household characteristics, the probability and cumulative distribution are obtained to scale the expenditure shares, preserving all the observations.

Secondly, the errors in the expenditure-share equations are exact linear combinations of the residuals of unconditional demand, which means that the observed separable group expenditures under multistage budgeting cannot be considered exogenous. This

can be resolved by establishing suitable instruments for expenditure variables, which demonstrates that instrumental variable estimation in nonlinear demand systems generates consistent outcomes. To mitigate endogeneity, the present study estimates least squares regressions at each stage to acquire fitted values for the related expenditures, which are used as instruments in the subsequent stages.

Finally, the demographic scaling technique allows for estimating the relationships between income and price elasticities of demand and demographic characteristics through estimated parameters. A unique characteristic of this study is its consideration of consumption-savings behavior to eliminate the endogeneity problem, which is frequently ignored in multi-stage budgeting. Moreover, this study has a novel feature, combining demographic scaling and accounting for censored dependent variables in systems of demand equations. The study finds that seafood consumption is perceived as a luxury good, and it is highly sensitive to price fluctuations. Moreover, these elasticities are even larger among households with higher restaurant, tobacco, and alcohol expenditures.

The last essay aims to portray the bioeconomic model of Turkish large-scale fisheries under the current stage of the fisheries regulations and a set of its counterfactuals, including alternative fishing season lengths, fishing capacities, and market shares of fish meal and fish oil (FMFO) factories. To this end, first, Turkish regulatory structure is positioned within the classes of fisheries regimes. Then, by using the parameters from the previous sections and other information obtained from the TurkStat Central Dissemination System (TurkStat MEDAS), a discrete-time, discrete-state dynamic programming methodology is applied under different fishing season lengths, fishing capacities, and FMFO market shares. As the stock and effort levels adjust daily, the prices adjust according to daily supply functions or the marginal cost of output to meet industry demands from commissioners and FMFO factories. As a result, the components of social welfare are obtained, and their long-term values are compared for alternative policies. The study finds that achieving maximum sustainable yield levels requires significant reductions in fishing capacity by around 33% and season length by 2 months. Moreover, these policies yield an overall welfare gain driven by consumer surplus despite the reductions in profitability. Finally, it is also demonstrated that policies that diminish the market influence of FMFO factories and intermediaries can mitigate these losses.

The remainder of the dissertation is organized as follows. Chapter 2 first estimates the bioeconomic parameters by employing a generalized fishery model. Then, it estimates a stochastic frontier model with inefficiency effects, using the stock estimates obtained by the generalized fishery model. Next, Chapter 3 estimates Turkish seafood demand by employing a novel Quadratic Almost Ideal Demand System (QUAIDS) approach, enhanced by multi-stage budgeting, censoring, and demographic scaling. Afterwards, by building on the parameters in previous chapters, Chapter 4 develops an analytical bioeconomic model to analyze the extends of existing fisheries regulations. Finally, concluding remarks policy suggestions and future research opportunities are provided in Chapter 5.

2 ESTIMATION OF BIOECONOMIC PARAMETERS AND TECHNICAL EFFICIENCY IN TURKISH LARGE-SCALE COASTAL FISHERIES

2.1 Introduction

In recent decades, capture fisheries and aquaculture sectors have been proven to be the crucial for global food security, driven by the rapid improvement of aquaculture, which is mainly fed by capture fisheries. On the other hand, capture fisheries have been stagnating due to significant challenges, including ocean warming, marine pollution, and overfishing. Among these, due to technological advancements and expanding markets, overfishing is arguably the most significant, leading to requirements for regulation. Similarly, in Turkey, the transition to a market economy in the 1980s has led to significant expansions in the harvest levels followed by rapid declines in the consecutive decade. Moreover, expanding industrial practices and use of more advanced technologies like sonar, echo sounder and cold storage units have irreversibly fastened overfishing. Although the Ministry of Agriculture and Forestry (TOB) is centrally responsible for fisheries management, there are many regulations addressing region-, gear-, and species-specific rules. However, the possible effects of technological developments are not addressed in these regulations. Moreover, there are regulations including marine protected areas, seasonal closures, and vessel buy-back programs that are not adequate to reduce overcapacity.

Since 2014, the Ministry and TurkStat have collaborated to conduct monthly surveys to collect pertinent information on maritime fisheries. In 2016, the Vessel Monitoring System (VMS) was established to regulate fishing operations of large-scale vessels and to collect more detailed data on maritime fishing activities. The VMS initiative utilizes GSM and satellite technologies to oversee the fishing activities of 1500 boats. The compilation of fishing data from vessels commenced with the utilization of electronic logbooks. Moreover, the technical support program "Initiation of Stock Assessment in the Turkish Fisheries System" was implemented in 2011 to enhance the infrastructure of the International Pacific Halibut Commission (IPHC) institutions. While they are relatively new, these datasets regarding fisheries have started to allow

for more comprehensive analyses of Turkish marine fisheries. Since 2014, TurkStat Fisheries Micro Dataset has systematically included detailed catch information about fishing units, including their technical characteristics like tonnage, gear type, fishing technologies and activities like operating hours, target species, and their catch sizes. Although information on small-scale fishing units is relatively limited as they are sampled and surveyed twice a year, all large-scale fishing units are surveyed monthly, satisfying the data requirements in this study.

TurkStat Fisheries Statistics classifies gear types used in Turkey as trawls (bottom and midwater), purse seines, beam trawls and dredges, hooks and longlines, entangling nets (gillnets, trammel nets, etc.), seine nets, drag nets, traps, and others. Most large-scale fishing units with vessels of at least 10 meters favor various trawls, purse seines, beam trawls, and dredges, which are infamous for their adverse environmental impacts at various levels. Especially bottom trawling, beam trawling, and dredging are known for their harm to the seafloor depending on their working principles, while purse seine and midwater trawls are more associated with bycatch of certain species (FAO, 2022).

The datasets list different fisheries technologies, including radar, sonar, echo sounder, GPS, radio set, generator, ice machine, and cold storage room. These technologies help provide navigational and communicational safety for workers and have the potential to increase efficiency and reduce bycatch of irrelevant species. However, they also increase fishing capacity and effort, which results in overfishing. Naevdal (2022) found that the technological developments necessitate an increase in the minimum size of stock required for sustainable fisheries and more conservative harvest rules. In other words, using advanced technology in fisheries can quickly deepen the existing overcapacity, which is one of the most dangerous factors endangering the long-term viability of fish stocks and the fishing units that rely on them.

The laws and regulations in Turkey's fisheries management primarily focus on marine conservation and supporting small-scale fishing units while reducing the number of large vessels. However, past experiences, studies, and statistics suggest that these attempts seem ineffective in mitigating either illegal and unreported fisheries or overfishing. Addressing these issues requires knowledge about the current biomass levels. Thus, the biological dynamics of fish populations, the determinants of harvest levels, and the interactions between natural dynamics and economic activities should be revealed.

The biological dynamics of fish populations include two components: intrinsic growth rate and environmental carrying capacity. While intrinsic growth rate refers to the population growth rate of a species when there is no external effect, environmental carrying capacity is the maximum population sustainable within the boundaries of a specific region. Along with the biological dynamics including initial stock level, intrinsic growth rate, and carrying capacity, fishing activities also determine the stock dynamics. As a result, the biomass in the next period is determined by current stock and harvest levels given the values of intrinsic growth rate and environmental carrying capacity.

Moreover, fishing activities are determined by fishing effort performed by fishing units as well as the current presence of fish populations in the sea. Thus, not only knowledge of the stock levels but also an appropriate definition of fishing effort is necessary. While stock levels are unknown, most standardized definitions of fishing effort include duration of fishing and values reflecting the size of vessels. Nevertheless, other technical properties of vessels cannot be standardized in the definition of effort.

This study first aims to estimate the intrinsic growth rate, carrying capacity, and parameters of the harvest function including effort elasticity and catchability coefficient. Based on the information provided by TurkStat Fisheries Micro Dataset (2015-2021), this study first calculates the fishing effort by multiplying the gross tonnage and total monthly hours spent at sea for each vessel using a specific gear and fishing in a region. To do so, if a fishing unit used multiple gears or fished in various areas, it is accounted as multiple distinct units in order to avoid confusion about the technical and geographical properties of its activities. Next, the parameters and associated monthly biomass levels are estimated via a modified generalized fisheries model inspired by Zhang & Smith (2011). Then, the estimated fish stock and fishing effort are incorporated into a stochastic frontier model with inefficiency effects suggested by Battese & Coelli (1995). These inefficiency effects include technical and geographic properties of fishing activities, such as gear type, technological equipment, and fishing region.

The rest of the chapter is organized as follows: Section 2.2 of this chapter reviews the relevant literature. Then, Section 2.3 explains the methodology summarized above in

detail. Next, Section 2.4 provides summary statistics from the datasets used. After Section 2.5 presents the results, Section 2.6 concludes.

2.2 Literature Review

The literature on technical efficiency analysis in fisheries mostly ignores the potential effect of the stock levels on the production and efficiency due to the lack of data on stock levels. However, if there are large variations in the stock levels in a given fishery, both parametric and non-parametric analyses may result in biased outcomes. The most popular approaches employed by efficiency and productivity studies in capture fisheries are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) (Van Nguyen et al., 2021; Van Nguyen & See, 2023).

Both methods have benefits and pitfalls. The most significant advantages of the, DEA as a non-parametric method, are that it allows for analyzing multiple outputs and does not require a functional form. However, these analyses cannot capture random errors which are essential in fisheries by nature. If the associated stock levels are missing in these analyses, the ignored error term become even larger. On the other hand, by adding a random error term next to the inefficiency component, SFA seems more appropriate in the efficiency analysis of fisheries. In addition, as a parametric approach, it is more suitable for the panel data analysis, providing insights about not only into the efficiency of fishing activities but also into the underlying production functions.

The main problem in employing SFA in fisheries is that it is highly complex, as it requires an appropriate functional form for the frontier, a distributional assumption for the inefficiency component, and a choice of various replaceable inputs that can be included in the analysis. To be more precise, while Esmaeili (2006) and Alvarez et al. (2020) used a Cobb-Douglas production function in the frontier, Coglan & Pascoe (2007) and Quijano et al. (2018) used it in a trans-log form. In addition, SFA allows for different distributional assumptions on the inefficiency part of the composite error term, including half-normal, truncated-normal, exponential, and gamma distributions. For example, Kirkley et al. (1995) assumed a half-normal distribution compared to others, mostly assuming a truncated-normal distribution. More related to data availability, most studies' choices of fixed and variable inputs involve the vessels' technical aspects and fishing durations rather than biomass and composite effort

variables standard in the production functions of bioeconomic models. These include but not limited to gross tonnage (Viswanathan et al., 2002), engine power, deck area, and gear length (Fousekis & Klonaris, 2003) as fixed inputs, and the number of crew members (Susilowati et al., 2005), fishing days or hours (Quijano et al., 2018), and fuel consumption (Dağtekin et al., 2021) as variable inputs. Despite these issues creating complexity in its applications, SFA remains a valuable tool for simultaneously estimating the units' production function and inefficiency level.

Despite the extensive tendency to use variables that can only be interpreted as components of the fishing effort, few studies acknowledge the importance of stock levels' impact on harvest and efficiency. As biomass data is unavailable for most waters worldwide, actual biomass values based on stock assessment reports are rare. Still, Yang et al. (2017) evaluated the technical efficiencies (TE) of fishing units by using actual stock data as an additional explanatory variable in the frontier. On the other hand, the remaining studies had to use different proxies for the stock biomass. To illustrate, Kirkley et al. (1995) developed one by calculating the average catch level per hour in the last towing. This calculation was based on the geometric mean of the catch by vessels in the same area, during the same period, and with the same dredge size. In their study, Dresdner et al. (2010) developed an abundance indicator by calculating the total amount of fish caught and dividing it by the number of days the fleet was active in a month. Then, they adjusted that value by considering the fleet's average capacity over a year. Nevertheless, none of these studies proposed a link between bioeconomic parameters and efficiency analysis. By using them in SFA, only Duy & Flaaten (2016) compared three stock proxy indexes, including one based on changes in the average level of catch per unit effort (CPUE) to be directly incorporated into the frontier, a CPUE-adjusted output measure and a composite stock effect index referring to the technical change component of the Malmquist productivity index (MPI) (Pascoe & Herrero, 2004). The last one was found to be more robust, although efficiency scores showed no differences.

In addition to different approaches to applying SFA, the purposes of the mentioned studies and their evaluations of technical efficiency (TE) vary. Nevertheless, it is worth noting that the ones incorporating biomass as a variable in their analyses provide more specific results than the others that interpret their findings to relate to fisheries policy. Some studies have considered the need for, or the effects of individual transferable

quotas (ITQs), property rights that allocate specific quotas to individual fishers, aiming to improve efficiency and sustainability. Kirkley et al. (1995) aimed to evaluate policies designed to enhance TE and reduce mortality rates. They found that efficient harvest in commercial fisheries is associated with resource abundance and the captain's ability to adapt to changing conditions. In addition, the regulatory policies, including crew size, dredge width, days-at-sea, vessel tracking systems, and minimum fish size restrictions, were found to be ineffective, and the intention to implement ITQs was affirmative as it could increase efficiency and reduce mortality and mitigate externalities arising from advanced technology. Susilowati et al. (2005) aimed to highlight the significance of property rights and the contradiction between private technical efficiency and social-technical efficiency in an open-access fishery. To them, private incentives increase fishers' exploitation rates, leading to overfishing and resource depletion; hence, implementing well-defined property rights, such as ITQs or effectively managed common property, could help achieve sustainable resource use and economic efficiency. Similarly, Jeon et al. (2006) also focused on property rights. For them, increasing TE without addressing property rights and fishing capacity can lead to resource depletion. Policies should balance the need to improve TE with measures to control fishing effort and protect resource stocks. This may involve better management of property rights and regulation of input use. Dresdner et al. (2010) aimed to estimate the effect of ITQs on fishery efficiency. They found that introducing ITQs had improved fleet efficiency.

Moreover, there are studies that focus on input controls in their analyses. Kompas et al. (2004) aimed to evaluate the impacts of input controls on TE of fisheries. They found a shift from regulated inputs to unregulated ones reduced efficiency. They suggested that alternative regulatory measures, such as individual output controls or a mix of input and output controls, might be more effective in promoting economic efficiency while ensuring sustainable fish stocks. Esmaeili (2006) also examined the impact of input controls on TE, suggesting that while these controls are intended to prevent overfishing and ensure sustainable practices, they can also inadvertently constrain technical efficiency by limiting fishers' ability to optimize their input mix.

Furthermore, some studies focus on the implications of vessel reduction programs. Coglan & Pascoe (2007) aimed to highlight the contradiction between the sustainability gains from decommissioning programs and the enhancements in human

capital in fisheries, along with associated technological developments. They found that while training programs can enhance individual productivity, they may also increase overall fishing effort, potentially counteracting conservation efforts. Thus, policies must balance these competing objectives. Yang et al. (2017) also focused on the buyback programs in overexploited fisheries. They suggested that vessels with larger sizes and enthusiastic owners should be considered when applying these programs as they are more efficient than others. Quijano et al. (2018) emphasized the inadequacy of buyback programs in a mixed fishery, suggesting that specific attributes of fleet segments and supporting these programs with regulations including limited seasons and quota regimes.

Finally, the remaining studies explore the alternative determinants of TE in fisheries. Viswanathan et al. (2002) evaluated TE as a measure of skipper skill. They found that it varies significantly by season, vessel size, and skipper ethnicity. Fousekis & Klonaris (2003) evaluated TE as an existing potential to increase short-run output without additional fishing effort. TE was found to be influenced by vessel and skipper characteristics, with newer vessels and engines, higher propulsion power, and the skipper's family background and education level positively affecting TE. The study identified that the fleet operates under increasing returns to scale, suggesting potential productivity gains with increased effort. However, these gains may be negated by adverse effects on resource stocks in the long term.

Alvarez & Schmidt (2006) evaluated the variance of the inefficiency component as skill and the variance of the error term as luck and made a comparison between them. They found that luck is more important in determining the catch levels; thus, the evaluations based solely on skipper skills may be misleading. Van Nguyen et al. (2019) evaluated the effect of regional economic differences in technical efficiencies of open-access fisheries. More developed regions were found to be more efficient than others. Alvarez et al. (2020) found that specialization in target species leads to less efficient harvest. Finally, Dağtekin et al. (2021) studied the determinants of efficiency, including the credit use and subsidy provisions to fishing units. They found that the subsidy rates positively affected efficiency, while credit rates had no significant effect. Hence, subsidies must be carefully regulated to prevent overfishing and ensure sustainable practices.

Since stock assessment data is unavailable for most fisheries, some methods are proposed to estimate stock biomass. Maunder & Punt (2013) provided a review of integrated analysis in fisheries stock assessment, including data requirements of the main types of analyses. Accordingly, most types of analyses require biological information, including catch-at-age data (cohort analysis, virtual population analyses), stock size and recruitment data (stock-recruitment analysis), information on natural mortality, growth rates, and fishery age-specific selectivity (yield-per-recruit analysis), and tagging data and information on length at release, length at recapture, and time at liberty such as tagging growth analysis.

More relevant to our study that rely on the economic data are surplus production models using catch and effort information in their analyses. Another review proposed by Kokkalis et al. (2024) explained the practices in surplus production models. They suggested that at least 15 years of time series information is necessary for an appropriate stock assessment based on surplus production models. However, they did not review panel data applications of stock estimation models.

Finally, Zhang & Smith (2011) proposed a generalized fishery model using a two-stage approach. They employed a long panel data set, including information about multiple vessels, gears, and regions. They also proposed methodological critiques based on some time series estimation practices, which they called CPUE estimators and CPUE-like estimators. The superiority of their model on the previous models is convincing; however, the constrained stock elasticity of 1 remains open to criticism. Moreover, assuming homogenous stocks is not realistic for an analysis of large geographical area.

Stock assessment practices are relatively new in Turkey. TOB (2019) stated that the Ministry's institutes have been carrying out monitoring studies by establishing the necessary infrastructure using acoustic methods. Stock determination studies have been carried out on important fish stocks in the country's seas and inland waters from time to time. In parallel with these, studies such as the determination of population parameters of commercial species, migration structure, reproductive characteristics and stomach content analyses are also conducted. Demirel et al. (2020) presented the first extensive assessment of 54 stocks harvested by Turkey in Eastern Mediterranean and Black Sea, using a catch maximum sustainable yield (CMSY) methodology (Froese et al., 2017; Martell & Froese, 2013) that requires a long time series of catch

and resilience data. By analyzing 50 years of data, they found that most stocks are at unsustainable levels, suggesting the need for a 50% decline in the fishing pressure.

Similar to how technical efficiency studies ignore the significance of stock levels in their analyses, stock estimation procedures also ignore the presence of inefficiencies in their models. This study first slightly modifies Zhang & Smith (2011) by adding technological and regional interactions in the first step and disaggregating total stock estimate into regional differences in the second. Then, the time- and region-specific stock estimates are incorporated into the stochastic frontier model in the third step, accounting for inefficiency effects as suggested by Battese & Coelli (1995). By accounting for the presence of technical inefficiency and its determinants, an unconstrained estimate for stock elasticity is obtained, which modifies the previously estimated effort elasticity and catchability coefficient.

2.3 Methodology

2.3.1 Estimation of Bioeconomic Parameters

2.3.1.1 Previous Models

A two-equation system is a commonly employed approach for estimating the dynamics of fish population growth using economic data from a fishery (Schaefer, 1954). Let S_t represent the stock biomass, Y_t represent the catch level, and E_t represent the fishing effort at month t. Then, the system of equations becomes:

$$Y_t = qE_tS_t \tag{2.1}$$

$$S_{t+1} = S_t + rS_t\left(1 - \frac{S_t}{K}\right) - Y_t \tag{2.2}$$

where the intrinsic growth rate, r, the carrying capacity, K, and the catchability coefficient, q, are unknown parameters to be estimated. In case of the missing stock levels, S_t's, in a data set, it is frequently proxied by catch per unit effort (CPUE), s_t, at time t, assuming $S_t = \frac{s_t}{q}$, and calculated by:

$$s_t = \frac{Y_t}{E_t} \tag{2.3}$$

by substituting $S_t = \frac{s_t}{q}$ in Equation (2.2), the following equation can be estimated by least squares (Pella & Tomlinson, 1969):

$$s_{t+1} = (1+r)s_t - \frac{r}{qK}s_t^2 - qY_t + \omega_t \tag{2.4}$$

where ω_t is the stochastic error term representing unobserved sources in stock dynamics. However, Schaefer's harvest function is highly restrictive as diminishing marginal productivity does not apply and the catch technology exhibits increasing returns to scale. In fact, it is a special case of the Cobb-Douglas harvest function (Morey, 1986):

$$Y_t = qE_t^{\alpha}S_t^{\beta} \tag{2.5}$$

where α is the effort elasticity and β is the stock elasticity. Then, the unobserved stock becomes:

$$S_t = \left(\frac{Y_t}{qE_t^{\alpha}}\right)^{\frac{1}{\beta}} \tag{2.6}$$

Substituting Equation (2.6) into (2.2), the following equation is obtained and estimated by maximum likelihood:

$$\left(\frac{Y_{t+1}}{qE_{t+1}^{\alpha}}\right)^{\frac{1}{\beta}} = (1+r)\left(\frac{Y_t}{qE_t^{\alpha}}\right)^{\frac{1}{\beta}} - \frac{r}{K}\left(\frac{Y_t}{qE_t^{\alpha}}\right)^{\frac{2}{\beta}} - Y_t + \omega_t \tag{2.7}$$

Nevertheless, as Zhang & Smith (2011) emphasized, the estimators obtained by this equation will be biased since it ignores the error in the Cobb-Douglas harvest function, which is included in the term in Equation (2.6). As a result, the composite error term of the equation will be correlated with the harvest level, Y_t.

Finally, in order to overcome the complications of previously suggested models, Zhang & Smith (2011) proposed a two-stage estimation procedure including the estimation of Equation (2.5) in the first stage and (2.4) in the second. To this end, they employed a long panel data of many fishing units from J different areas and G different gears. In this case, the Equation (2.5) takes the form:

$$Y_{ijgt} = q_{ijgt}E_{ijgt}^{\alpha_g}S_t^{\beta}e^{\varepsilon_{ijgt}}, \quad i \in \{1,..,I\},\ t \in \{1,..,T\},\ j \in \{1,..,J\},\ g \in \{1,..,G\} \tag{2.8}$$

for fishing unit i, at time t, in region j, using gear, g. The function can be linearized by taking the logarithms of both sides:

$$ln(Y_{ijgt}) = ln(q_{ijgt}) + \alpha_g ln(E_{ijgt}) + \beta ln(S_t) + \varepsilon_{ijgt} \tag{2.9}$$

Zhang & Smith (2011) have assumed an individual-, time-, area- and gear-specific catchability coefficient as:

$$q_{ijgt} = e^{\gamma_g + \delta_j + \kappa_{ijgt}} \tag{2.10}$$

where γ_g and δ_r are gear- and area-specific constants and κ_{ijgt} is an error term to capture unobserved differences. Substituting Equation (2.10) into (2.9), the following equation is obtained:

$$ln(Y_{ijgt}) = \gamma_g + \delta_j + \alpha_g ln(E_{ijgt}) + \beta ln(S_t) + \varepsilon_{ijgt} + \kappa_{ijgt} \tag{2.11}$$

In this equation, the dummy variables for $G - 1$ gear types and $J - 1$ areas and effort are observed but stock biomass, $\beta ln(S_t)$, and the base dummy $\gamma_1 + \delta_1$ are not. Setting the base dummy at $g = j = 1$ for the dummy variables and estimating (2.11) with fixed effects, the estimator of the intercept becomes:

$$ln(C_t) = \gamma_1 + \delta_1 + \beta ln(S_t) \tag{2.12}$$

Resulting in the equation:

$$ln(Y_{ijgt}) = ln(C_t) + \sum_{g=2}^{G} \gamma_g + \sum_{r=2}^{J} \delta_j + \sum_{g=2}^{G} \alpha_g \, ln(E_{ijgt}) + \varepsilon_{ijgt} + \kappa_{ijgt} \tag{2.13}$$

To simplify, let $y_{itrg} = ln(Y_{itrg})$, $c_{t11} = ln(C_{t11})$, and $\boldsymbol{z'_{itrg}\rho}$ be the identifiable part of the equation, then, the index of stock abundance can be estimated as:

$$\widehat{c_t} = \overline{y_t} - \boldsymbol{\overline{z}_t'\widehat{\rho}} \tag{2.14}$$

where $\overline{y_t} = n_t^{-1} \sum_{i,r,g} y_{itrg}$ and $\boldsymbol{\overline{z}_t} = n_t^{-1} \sum_{i,r,g} \boldsymbol{z_{itrg}}$. Let $q = e^{\gamma_1 + \delta_1}$ and $e^{\widehat{c_t}} = \widehat{C_t}$. Then, from (2.12) and (2.14), the stock level to be estimated is:

$$\widehat{S_t} = \left(\frac{\widehat{C_t}}{q}\right)^{\frac{1}{\beta}} \tag{2.15}$$

Restricting $\beta = 1$ and substituting (2.15) into (2.4), the parameters $\hat{r}$, $\widehat{q_{11}}$, and $\widehat{K}$ can be estimated through feasible generalized least squares (FGLS) from the following equation:

$$\widehat{C_{t+1}} = (1 + r)\widehat{C_t} - \frac{r}{qK}\widehat{C_t}^2 - qY_t + \eta_t \tag{2.16}$$

where $\eta_t = q\omega_t$. As a result, the estimated stock is

$$\widehat{S_t} = \frac{\widehat{C_t}}{\hat{q}} \tag{2.17}$$

and the estimated sustainable yield, $\widehat{SY_t}$, for each period is:

$$\widehat{SY_t} = \hat{r}\widehat{S_t}\left(1 - \frac{\widehat{S_t}}{\widehat{K}}\right) \tag{2.18}$$

Finally, the maximum sustainable yield, $\widehat{MSY}^*$, approximates as:

$$\widehat{MSY}^* = \frac{\hat{r}\widehat{K}}{4} \tag{2.19}$$

which is the largest level of harvest that can sustainably be acquired provided that the stock level is around half of the carrying capacity.

2.3.1.2 A Modified Generalized Fishery Model

Zhang & Smith's generalized fishery model is based on a series of assumptions. First, they defined the fishing effort as the multiplication of crew size and number of days in a month. On the other hand, the definition of fishing effort in this study is in alignment with Regulation (EU) No 1343/2011, Article 3, establishing it by the sentence *"... the product resulting from multiplying the capacity of a fishing vessel, expressed either in kW or in GT (gross tonnage), by the activity expressed in number of days at sea."*. This intuitively makes sense as the fishing capacity defined in gross tonnage carries information about the vessel size, number of crew members, and the technological diversification of the vessels; and the number of days itself reflects the intention to use that capacity. The only distinction in this study is that the number of days is multiplied by the average daily sailing hours to introduce the intensity of the effort and make it more variable across observations. As a result, the fishing effort is computed as:

$$E_{it} = W_{it}D_{it}h_{it} \tag{2.20}$$

where W is the gross tonnage of the vessel, D is the number of days the unit operated, and h is the average daily hours of the operations.

Secondly, the trip level data set used by Zhang & Smith (2011) has contained some observations including trips in multiple areas using multiple gears. The catch and effort of these trips were evenly distributed among gears and areas. Conversely, TurkStat Fisheries Statistics Micro Dataset directly contains monthly information of fishing

units. For each fishing unit, multiple rows of information are defined for the catch level of each species using each type of gear in each region. In this study, aggregating for commercially valuable species, each fishing unit is defined as multiple units if they used multiple gears in multiple regions.

Next, Zhang & Smith (2011) have assumed that the stock is homogenous in all related regions and the same for all fishing zones. Nevertheless, this assumption can be misleading intuitively. Considering a large coastline as the study area, actual stock levels can vary between statistical fishing zones. This can be verified by the number of vessels and the total catch in zone and time. In addition, since most fishing units are active in only a few fishing zones, it is not possible to argue that all face the same stock level. Besides, the fact that their model defines specific catchability coefficients in Equation (2.10) can be interpreted as a contradictive practice with this assumption. If there are such coefficients, there must be distinct stock levels for each zone.

In this study, Zhang & Smith's generalized fishery model is slightly modified by dividing total stock level into regional stock levels. Moreover, fishing technology is considered a mix of the use of sonar and echo sounder and choice of the gear type. Thus, time-specific stock in Equation (2.8) is replaced by a time- and region-specific one, S_{jt}, and gear-specific catch-effort elasticity is replaced by the technology-specific one, α_{abg}, where $a, b \in \{0,1\}$ take the value of 1 for use of sonar (a) and echo sounder (b). Moreover, it is assumed that catchability coefficient, q, is unique for the generalized fishery model. Replacing $\beta = 1$, the harvest function becomes:

$$Y_{itabgj} = qE_{itabgj}^{\alpha_{abg}} S_{tj} e^{\varepsilon_{itabgj}} \tag{2.21}$$

which is equivalent to:

$$\begin{aligned} ln(Y_{itabgj}) = & \sum_{a=0}^{1}\sum_{b=0}^{1}\sum_{g=1}^{G}\sum_{j=1}^{J} \psi_{abgj} D_{itabgj} + \alpha ln(E_{itabgj}) \\ & + \sum_{a=0}^{1}\sum_{b=0}^{1}\sum_{g=1}^{G} \alpha_{abg} ln(E_{itabgj}) D_{itabgj} + ln(S_{tj}) \\ & + \varepsilon_{itabgj} \end{aligned} \tag{2.22}$$

The constant term represents the sum of the two unidentified parts, ψ_{0011} and $ln(S_{tj})$. For $G = 8, J = 5$, and assuming $q = e^{\psi_{0011}}$, it becomes

$$ln(C_{tj}) = ln(q) + ln(S_{tj}) \tag{2.23}$$

Equation (2.22) can be estimated by a fixed effects regression. For simplicity, its predicted equation can be written as

$$\widehat{y_{itabgJ}} = \boldsymbol{z'_{itabgj}}\widehat{\boldsymbol{\gamma}} + \widehat{lnC_{tJ}} \tag{2.24}$$

Then, the logarithm of the stock index for each region and time, $\overline{\widehat{ln(C_{tJ})}}$, can be identified by the following:

$$\overline{\widehat{ln(C_{tJ})}} = n_{jt}^{-1} \sum_{iabj} \widehat{y_{itabgJ}} - n_{jt}^{-1} \sum_{iabj} \boldsymbol{z'_{itabgj}}\,\widehat{\boldsymbol{\gamma}} \tag{2.25}$$

Substituting it into Equation (2.23), exponentiating, and rewriting for S_{tj}, the following is obtained:

$$S_{tj} = \frac{\overline{\widehat{C_{tJ}}}}{q} \tag{2.26}$$

In order to estimate S_{tj}, an estimate of the catchability coefficient is necessary. It can be estimated by a panel data analogue of the Equation (2.2):

$$S_{t+1,j} = S_{tj} + rS_{tj}\left(1 - \frac{S_{tj}}{\overline{K}}\right) - Y_{tj} + \kappa_{tj} \tag{2.27}$$

where $\overline{K} = \frac{1}{J}\sum_{r=1}^{J} K_r$ is the average carrying capacity of the regions. Substituting the Equation (2.26) into (2.27) and rewriting the equation, the following equation is obtained:

$$\Delta\overline{\widehat{C_{tJ}}} = r\overline{\widehat{C_{tJ}}} - V\overline{\widehat{C_{tJ}}}^{2} - qY_{tj} + \kappa'_{tj} \tag{2.28}$$

where $\kappa'_{tj} = q\kappa_{tj}$ and $V = \frac{r}{q\overline{K}}$. To impose positivity constraints for the parameters, they can be defined as exponents of some terms such that $r = e^{\zeta_1}$, $V = e^{\zeta_2}$, and $q = e^{\zeta_3}$. Thus, the following equation can be estimated by nonlinear least squares (NLS):

$$\Delta\overline{\widehat{C_{tJ}}} = e^{\zeta_1}\overline{\widehat{C_{tJ}}} - e^{\zeta_2}\overline{\widehat{C_{tJ}}}^{2} - e^{\zeta_3}Y_{tj} + \kappa'_{tj} \tag{2.29}$$

As a result, the estimates for intrinsic growth rate, catchability coefficient, carrying capacity, and the stock levels are obtained as:

$$\hat{r} = e^{\widehat{\zeta_1}}, \qquad \hat{V} = e^{\widehat{\zeta_2}}, \qquad \hat{q} = e^{\widehat{\zeta_3}}, \qquad \widehat{K} = J\frac{\hat{r}}{\hat{q}\hat{V}}, \qquad \widehat{S_{tJ}} = \frac{\overline{\widehat{C_{tJ}}}}{\hat{q}} \tag{2.30}$$

2.3.2 Harvest Function under Inefficiency Effects

There are two problems in the generalized fisheries model and the modification suggested above. First, since the theoretical harvest function is based on the microeconomic theory, they assume efficient utilization of fishing effort and stock biomass. Although the parameters in equations (2.13) and (2.22) helps compare the regional and technological differences in efficiency levels, this only occurs on the production possibilities frontier. Another problem in these models is that they assume a stock elasticity of one, leading to an imposition of increasing returns to scale if effort elasticity is positive. Although it is theoretically possible to estimate β in Equation (2.5), it remains computationally infeasible using likelihood-based models. If it is less than one, it is possible that the catchability coefficient is underestimated. Still, the estimated stock index and associated proportional stock reflect the necessary regional and seasonal variations in the stock biomass.

In order to overcome these issues, the production frontier and time-varying inefficiency effects are estimated by incorporating the stock estimate $\widehat{S_{tj}}$ into the model. The panel data stochastic frontier analysis developed by Battese & Coelli (1995) is a well-suited one compared to other methods as it simultaneously estimates the frontier and the determinants of inefficiency. The frontier equation of the model can be written as:

$$ln(Y_{it}) = \vartheta_0 + \vartheta_1 ln\left(\widehat{S_{tj}}\right) + \vartheta_2 ln(E_{it}) + \varrho_{itj} \tag{2.31}$$

where the composed error term $\varrho_{itj} = -u_{itj} + v_{itj}$. $u_{itj} \geq 0$ is the term reflecting technical inefficiency, which is assumed to be an independently distributed random variable with a truncated normal distribution obtained by truncation at zero point of a normal distribution with mean $\boldsymbol{z_{itj}\eta}$ and constant variance σ_u^2. v_{itj} is assumed to be an identically and independently distributed stochastic error term with standard normal distribution with mean zero and constant variance σ_v^2. It is also assumed that u_{itj} and v_{itj} are independent of each other.

Equation (2.31) is a redefined harvest function reflecting the maximum production possibilities under the existence of different technical and regional characteristics. Thus, the parameter ϑ_0 is equivalent to the logarithm of the catchability coefficient, $q_{SFA} = e^{\vartheta_0}$. Besides, there is no constraints imposed on the stock elasticity, ϑ_1.

Finally, the effort elasticity, ϑ_2, is a generalized one reflecting average returns to effort of all vessels regardless of their technical and regional characteristics.

Next, the model for technical inefficiency effects is written as:

$$u_{itj} = f(\boldsymbol{z_{itj}};\, \boldsymbol{\eta}) + \ell_{itj} \tag{2.32}$$

where ℓ_{itj} is assumed to be a random variable with truncated normal distribution with zero-mean, constant variance and the point of truncation at $-\boldsymbol{z_{itj}\eta}$, that is $\ell_{itj} \geq -\boldsymbol{z_{itj}\eta}$. These assumptions provide two advantages. First, they are consistent with the assumptions made for u_{itj} so that any estimation result provided by this analysis cannot be contradictive. Secondly, the mean of the distribution of u_{itj} ($\boldsymbol{z_{itj}\eta}$) is not required to be positive for each observation. The vector, $\boldsymbol{z_{itj}}$, involves a set of possible variables that can determine the distance from the frontier. All variables except the logarithm of engine power are dummy variables for eight different gears, five regions, and the availability of sonar, echo sounder, cold conservation room and generator on the vessel.

Finally, it is assumed that variance of the inefficiency term is constant, but the variance of the stochastic error term is a function of the effort level, which needs to be corrected. Hence, the following equation is also simultaneously estimated with equations (2.31) and (2.32):

$$\sigma_v^2 = \pi_0 + \pi_1 ln(E_{it}) + \varsigma_{it} \tag{2.33}$$

In other words, if π_1 is significantly different from zero, heteroskedasticity is present in the stochastic error term.

2.4 Data and Descriptive Statistics

This study utilizes the TurkStat Fisheries Statistics Micro Dataset from January 2015 to December 2021. Only large-scale fishing units with vessels of at least 10 meters are included in the monthly survey, while others are excluded due to insufficient information. Several fishing units employ various fishing gears and operate in multiple areas within a single month. In such cases, for simplicity, a fishing unit that possesses multiple characteristics is treated as multiple distinct units for each unique combination of its characteristics. Fortunately, the dataset contains information for

every possible combination. Moreover, all reported catch levels are aggregated for each observation in tons. With these approaches, the data structure, and eliminating some vessels with poor information, a total of 69107 observations or around 1234 average monthly units are obtained. Besides, these observations include 4904 different units with an average of 14.1 months of appearance. As there is a fishing ban between April 15th and September 1st each year, the analysis is conducted for 56 months. September and October are the busiest fishing months while April is negatively affected by the short period it includes (Table 2.1).

Table 2.1 Frequencies of Seasons

Season	Frequency	Percentage
January	7823	11.32
February	8507	12.31
March	8068	11.67
April	6988	10.11
September	9858	14.26
October	10128	14.66
November	9066	13.12
December	8669	12.54

Source: TurkStat Fisheries Statistics Micro Data Set

The dataset contains essential information for each month, including district level location and duration (days and daily average hours) of fishing trips, the type of gear utilized, the quantities and species of fish captured, and technical characteristics about vessels, such as the presence of sonar, echo sounder, generator, and cold storage room, in addition to their tonnage, and engine power.

Table 2.2 Frequencies of Gear Types

Gear Type	Frequency	Percentage
Unspecified Trawls	4277	6.19
Bottom Trawls	23597	34.15
Midwater Trawls	4476	6.48
Purse Seines	11932	17.27
Beam Trawls or Dredges	7169	10.37
Entangling Nets	11876	17.18
Surrounding or Cast Nets	3765	5.45
Other Gears	2015	2.92

Source: TurkStat Fisheries Statistics Micro Data Set

While there are numerous gear subclassifications in the survey, the primary classification is prioritized and the types with relatively small quantities are grouped together. Consequently, a total of eight distinct gear categories are identified. The predominant types of fishing gears include bottom trawls, midwater trawls, purse

seines, beam trawls or dredges, entangling nets, surrounding or cast nets, as well as other gears such as lines, longlines, drift nets, fykes, traps, and other unclassified gears. For certain months, when the trawl type is not specified, an additional category of unspecified trawls is also included. The use of bottom trawls is by far the most observed among the gears.

Table 2.3 Shares of Additional Technologies

Additional Technology	Percentage
Sonar	33.97
Echo Sounder	87.56
Generator	39.17
Cold Conservation Room	88.67

Source: TurkStat Fisheries Statistics Micro Data Set

In addition to various gears, some additional technologies can be present on the vessels. The most important ones are fish-finding sonars and echo sounders. Although sonar use is relatively rare, majority of observations use echo sounders and have a cold conservation room. Finally, only 39.17% of observations benefit from an additional power generator along with the already available engines (Table 2.3).

Turkstat categorizes Turkey's coastal areas into five primary fishing regions across four seas. Of these, the Black Sea coasts are divided into two regions. The eastern section of the area lies between Artvin and Sinop, while the western section is situated between Kastamonu and Kırklareli. The fishing operations conducted in the Bosporus and Dardanelles Straits are encompassed within the boundaries of the Marmara Sea. The two remaining fishing areas are the Aegean Sea, which extends to its southernmost point in Muğla, and the Levantine (Eastern Mediterranean) Sea, which reaches its westernmost point in Antalya. Unexpectedly, the observation in Eastern Black Sea is lower than others.

Table 2.4 Frequencies of Regions

Region	Frequency	Percentage
Eastern Black Sea	10574	15.30
Western Black Sea	16531	23.92
Marmara Sea	11512	16.66
Aegean Sea	17078	24.71
Levantine Sea	13412	19.41

Source: TurkStat Fisheries Statistics Micro Data Set

As defined in Equation (2.20), the effort level is defined as the multiplication of the tonnage and the total monthly working hours. The lowest average monthly effort level

is observed in the Levantine Sea with the lowest variation in this effort level (Table 2.5). It is also the case for the catch levels in the same region, with the lowest estimated catch per unit effort (CPUE) (Table 2.6).

Table 2.5 Regional Average and Volatility of Effort Levels

Region	Average Monthly Effort	Standard Deviation	Coefficient of Variation
Eastern Black Sea	3591.77	2118.94	0.59
Western Black Sea	3917.53	2332.41	0.60
Marmara Sea	2468.56	1373.84	0.56
Aegean Sea	4221.22	1949.32	0.46
Levantine Sea	2205.94	613.21	0.28

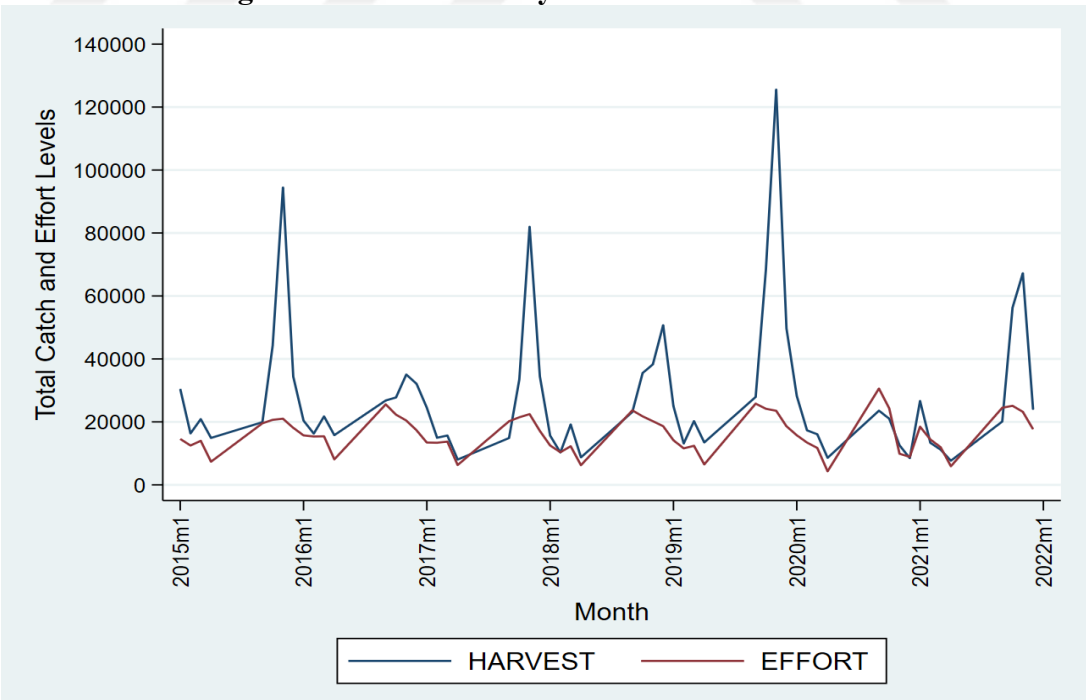
Source: TurkStat Fisheries Statistics Micro Data Set

Table 2.6 Regional Average and Volatility of Harvest Levels

Region	Average Monthly Harvest	Standard Deviation	Coefficient of Variation	CPUE
Eastern Black Sea	14122.38	17254.63	1.22	3.93
Western Black Sea	6825.03	5387.36	0.79	1.74
Marmara Sea	2998.45	3109.38	1.04	1.22
Aegean Sea	3929.61	1674.68	0.43	0.93
Levantine Sea	815.61	332.06	0.41	0.37

Source: TurkStat Fisheries Statistics Micro Data Set

Figure 2.1 Total Monthly Catch and Effort Levels



Source: TurkStat Fisheries Statistics Micro Data Set

Despite the largest effort levels in the Aegean Sea, it is not as productive as the ones in its northern neighbors. The CPUE grows on the way from Marmara Sea to the

Eastern Black Sea. Although the effort levels in the Eastern Black Sea are lower than Aegean and Western Black Sea, by far the greatest harvest levels are observed there.

Figure 2.1 depicts the total monthly harvest and catch levels in Turkey. It can be inferred that the effort level is relatively stable compared to harvest. In other words, while the large-scale fishing units display similar behavior each year, return to this stable activity is highly volatile, illustrating the importance of the varying stock levels. This also demonstrates that the policies aiming to reduce the number of vessels cannot eliminate the fishing effort.

2.5 Results

2.5.1 Estimation of Bioeconomic Parameters

The fixed effect regression depicted in Equation (2.22) estimates at most 192 parameters depending on the technological and regional characteristics of the observations. Table 2.7 summarizes the results. The coefficients of independent variables are found to be jointly significant. Besides, the overall coefficient of determination shows that 56.4% of the variations in the logarithmic harvest level can be explained by the variations in the independent variables. While the estimate that $\sigma_\varepsilon = 0.863$ measures the standard deviation of the overall error term, $\sigma_u = 1.161$ measures the ones due to the time variations in the fixed effect, $ln(S_{tj})$, and individually invariant but time-variant dummies, the parameters of which are omitted due to this reason. Then, the interclass correlation, $\rho = \frac{\sigma_u^2}{\sigma_u^2+\sigma_\varepsilon^2}$, shows that 64.4% of the variance is due to σ_u. The correlation between the within-group errors and regressors is found to be -0.011, which is low as desired. Finally, the hypothesis that all within-group errors are zero is rejected.

The coefficient of the effort level, or the elasticity of effort of the base group, is found to be $\alpha = 0.767$, which is significant. The size of the estimate indicates decreasing returns to effort, which is the only controllable part of the fisheries policy. Unless the stock level is abundant adequately, a reduction in the average fishing effort seems necessary for the fisheries policy. Moreover, all α_{abg}'s are insignificant at 95% significance level except two groups of technologies that ignore the use of sonar and echo sounder. Among these, the total coefficient of the logarithmic effort level for purse seiners is $\alpha_{004} = 0.239$, and for midwater trawlers it is $\alpha_{003} = 0.209$.

Table 2.7 Parameter Estimates of the Fixed Effects Regression

Par.	Est.	Par.	Est.	Par.	Est.	Par.	Est.
$Int.$	-0.156 (0.108)	ψ_{0051}	1.114*** (0.397)	ψ_{0111}	0.462 (0.392)	ψ_{0151}	1.205*** (0.392)
ψ_{0012}	-0.975*** (0.36)	ψ_{0052}	0.805** (0.333)	ψ_{0112}	-0.92*** (0.316)	ψ_{0152}	1.228*** (0.315)
ψ_{0013}	1.135 (1.238)	ψ_{0053}	0.335** (0.165)	ψ_{0113}	0.552* (0.294)	ψ_{0153}	0.161 (0.156)
ψ_{0014}	0.271 (0.292)	ψ_{0054}	-0.158 (0.33)	ψ_{0114}	0.092 (0.156)	ψ_{0154}	0.192 (0.221)
ψ_{0015}	0.561** (0.238)	ψ_{0055}	Empty	ψ_{0115}	0.411** (0.181)	ψ_{0155}	0.071 (0.563)
ψ_{0021}	-0.261 (0.398)	ψ_{0061}	-0.431 (0.393)	ψ_{0121}	-0.277 (0.388)	ψ_{0161}	-0.213 (0.392)
ψ_{0022}	-1.026*** (0.319)	ψ_{0062}	-0.794** (0.321)	ψ_{0122}	-0.957*** (0.314)	ψ_{0162}	-0.919*** (0.316)
ψ_{0023}	0.222 (0.422)	ψ_{0063}	-0.236 (0.178)	ψ_{0123}	0.263 (0.185)	ψ_{0163}	-0.087 (0.157)
ψ_{0024}	-0.02 (0.178)	ψ_{0064}	-0.157 (0.141)	ψ_{0124}	0.181 (0.151)	ψ_{0164}	-0.185 (0.125)
ψ_{0025}	0.107 (0.182)	ψ_{0065}	-0.175 (0.171)	ψ_{0125}	0.337* (0.176)	ψ_{0165}	-0.064 (0.17)
ψ_{0031}	0.868* (0.469)	ψ_{0071}	0.03 (0.402)	ψ_{0131}	1.218*** (0.39)	ψ_{0171}	-0.124 (0.398)
ψ_{0032}	-0.966*** (0.361)	ψ_{0072}	-0.684** (0.323)	ψ_{0132}	-0.388 (0.318)	ψ_{0172}	-0.966*** (0.316)
ψ_{0033}	Omitted	ψ_{0073}	-0.43** (0.197)	ψ_{0133}	1.077*** (0.365)	ψ_{0173}	-0.211 (0.158)
ψ_{0034}	Empty	ψ_{0074}	-0.174 (0.235)	ψ_{0134}	-0.168 (0.273)	ψ_{0174}	-0.233* (0.132)
ψ_{0035}	0.057 (0.535)	ψ_{0075}	0.247 (0.251)	ψ_{0135}	-0.07 (0.342)	ψ_{0175}	0.537** (0.238)
ψ_{0041}	0.459 (0.486)	ψ_{0081}	0.044 (0.482)	ψ_{0141}	0.374 (0.41)	ψ_{0181}	1.608*** (0.49)
ψ_{0042}	-0.589* (0.344)	ψ_{0082}	-1.219*** (0.371)	ψ_{0142}	-0.805** (0.321)	ψ_{0182}	0.045 (0.315)
ψ_{0043}	0.251 (0.287)	ψ_{0083}	0.427* (0.218)	ψ_{0143}	0.626*** (0.173)	ψ_{0183}	0.081 (0.155)
ψ_{0044}	0.768 (0.578)	ψ_{0084}	-0.277 (0.205)	ψ_{0144}	1.399*** (0.172)	ψ_{0184}	-0.387*** (0.131)
ψ_{0045}	0.431 (0.348)	ψ_{0085}	-0.534*** (0.181)	ψ_{0145}	1.073*** (0.201)	ψ_{0185}	-0.452** (0.175)

Table 2.7 Parameter Estimates of the Fixed Effects Regression (Cont'd)

Par.	Est.	Par.	Est.	Par.	Est.	Par.	Est.
ψ_{1011}	0.914 (0.982)	ψ_{1051}	1.46*** (0.426)	ψ_{1111}	0.326 (0.402)	ψ_{1151}	1.198*** (0.405)
ψ_{1012}	-0.651 (0.41)	ψ_{1052}	0.995** (0.394)	ψ_{1112}	-0.501 (0.328)	ψ_{1152}	1.022*** (0.335)
ψ_{1013}	Empty	ψ_{1053}	0.216 (0.184)	ψ_{1113}	0.933*** (0.338)	ψ_{1153}	0.184 (0.162)
ψ_{1014}	0.167 (0.374)	ψ_{1054}	Omitted	ψ_{1114}	0.324* (0.183)	ψ_{1154}	1.075** (0.45)
ψ_{1015}	0.351 (0.266)	ψ_{1055}	0.829 (1.089)	ψ_{1115}	0.586*** (0.197)	ψ_{1155}	Empty
ψ_{1021}	-0.747 (0.552)	ψ_{1061}	-0.438 (0.443)	ψ_{1121}	-0.329 (0.391)	ψ_{1161}	-0.029 (0.408)
ψ_{1022}	-0.952*** (0.327)	ψ_{1062}	-0.866** (0.347)	ψ_{1122}	-0.839*** (0.316)	ψ_{1162}	-0.878*** (0.323)
ψ_{1023}	-0.222 (0.502)	ψ_{1063}	-0.312 (0.202)	ψ_{1123}	0.8*** (0.204)	ψ_{1163}	0.138 (0.171)
ψ_{1024}	0.304 (0.19)	ψ_{1064}	-0.361*** (0.138)	ψ_{1124}	0.196 (0.155)	ψ_{1164}	-0.17 (0.125)
ψ_{1025}	0.22 (0.191)	ψ_{1065}	-0.142 (0.176)	ψ_{1125}	0.305* (0.18)	ψ_{1165}	-0.12 (0.176)
ψ_{1031}	0.683 (0.57)	ψ_{1071}	0.291 (0.558)	ψ_{1131}	0.948** (0.394)	ψ_{1171}	0.495 (0.513)
ψ_{1032}	-1.362*** (0.485)	ψ_{1072}	-1.447*** (0.362)	ψ_{1132}	-0.383 (0.323)	ψ_{1172}	-1.113*** (0.331)
ψ_{1033}	-0.518 (1.322)	ψ_{1073}	-0.449** (0.202)	ψ_{1133}	1.195*** (0.288)	ψ_{1173}	0.021 (0.177)
ψ_{1034}	0.416 (0.731)	ψ_{1074}	-0.356** (0.16)	ψ_{1134}	1.094*** (0.273)	ψ_{1174}	-0.061 (0.131)
ψ_{1035}	Empty	ψ_{1075}	0.41 (0.31)	ψ_{1135}	-0.044 (0.89)	ψ_{1175}	0.604** (0.278)
ψ_{1041}	0.362 (1.128)	ψ_{1081}	Empty	ψ_{1141}	0.599 (0.397)	ψ_{1181}	Empty
ψ_{1042}	-0.674 (0.43)	ψ_{1082}	-0.307 (0.456)	ψ_{1142}	-0.403 (0.319)	ψ_{1182}	Omitted
ψ_{1043}	0.367 (0.274)	ψ_{1083}	-0.217 (0.215)	ψ_{1143}	0.79*** (0.17)	ψ_{1183}	Omitted
ψ_{1044}	0.544 (0.566)	ψ_{1084}	0.064 (0.216)	ψ_{1144}	0.948*** (0.153)	ψ_{1184}	Omitted
ψ_{1045}	0.404 (0.317)	ψ_{1085}	-0.419** (0.203)	ψ_{1145}	1.476*** (0.194)	ψ_{1185}	Omitted

Table 2.7 Parameter Estimates of the Fixed Effects Regression (Cont'd)

Par.	Est.	Par.	Est.
α	0.767***	α_{101}	-0.093
	(0.077)		(0.139)
α_{002}	0.123	α_{102}	0.027
	(0.081)		(0.085)
α_{003}	0.239**	α_{103}	0.223
	(0.109)		(0.195)
α_{004}	0.209**	α_{104}	0.167
	(0.102)		(0.139)
α_{005}	0.005	α_{105}	-0.007
	(0.087)		(0.109)
α_{006}	0.093	α_{106}	-0.035
	(0.079)		(0.083)
α_{007}	0.034	α_{107}	-0.092
	(0.09)		(0.095)
α_{008}	0.069	α_{108}	-0.049
	(0.092)		(0.094)
α_{011}	0.014	α_{111}	-0.113
	(0.078)		(0.084)
α_{012}	-0.017	α_{112}	-0.048
	(0.077)		(0.078)
α_{013}	-0.087	α_{113}	-0.045
	(0.079)		(0.081)
α_{014}	0.105	α_{114}	0.041
	(0.081)		(0.078)
α_{015}	0.051	α_{115}	0.006
	(0.078)		(0.084)
α_{016}	0.112	α_{116}	0.078
	(0.078)		(0.079)
α_{017}	0.037	α_{117}	0.14*
	(0.08)		(0.084)
α_{018}	0.004	α_{118}	-0.027
	(0.082)		(0.095)
σ_u		*1.161*	
σ_ε		*0.863*	
ρ		*0.644*	
$F(178, 64025)$		*175.960****	
R^2 *(Within)*		*0.329*	
R^2 *(Between)*		*0.644*	
R^2 *(Overall)*		*0.564*	
$Corr(u_i, \mathbf{z'}_{itabgj})$		*-0.011*	
$F(4903,64025)$		*6.82****	
N		*69107*	
# of ID's		*4904*	

Standard errors in parentheses.

*** (p<0.01), ** (p<0.05), * (p<0.1).*

Next, the intercept representing the sum of the two unidentified parts, ψ_{0011} and $ln(S_{tj})$, is very low compared to its standard error. Since it is insignificant, the average of the stock indices for all observations is zero. However, it does not mean that the base parameter, ψ_{0011}, and the fixed effect or the logarithm of the stock level are insignificant. In fact, they can be considered having different signs for each observation. Finally, the coefficients on dummy variables are valuable in explaining the shifts in the harvest levels by mix of technology and regional characteristics. Some parameters are omitted because the associated dummies are either invariant across individuals or correlated with another or due to no observations regarding the given mix of characteristics.

Table 2.8 illustrates that, considering the average significant ψ_{abgj} coefficients by each characteristic, sonar users have an important advantage compared to the ones that do not use them given a certain level of effort. Similarly, use of echo sounder leads to even a greater positive shift. If we rank the effect of the choice of gear type, beam trawl or dredge is on the top of the list, whereas surrounding or cast nets is at the bottom. It is Eastern Black Sea that provide the harvest levels compared to Western Black Sea providing the lowest levels with the same level of effort.

Table 2.8 Efficiency Shift by Technical and Regional Characteristics

	Characteristic	**Average Coefficient**
Technology	Sonar	0.056
	Echo Sounder	0.274
Gear Choice	Unspecified Trawl	0.030
	Bottom Trawl	-0.149
	Midwater Trawl	0.160
	Purse Seine	0.275
	Beam Trawl or Dredge	0.522
	Entangling Net	-0.191
	Surrounding or Cast Net	-0.215
	Other Gear	-0.049
Location	Eastern Black S.	0.273
	Western Black S.	-0.426
	Marmara S.	0.166
	Aegean S.	0.107
	Levantine S.	0.120

Source: Own Calculations

All the results depicted in Table 2.7 can simply be summarized by Equation (2.24). In the next stage, 280 stock indexes for 5 regions and 56 months are first obtained by Equation (2.25). In order to estimate the parameters in Equation (2.29), the

independent variable is acquired through the first difference of the index, reducing the number of observations to 240 as there are no observations before 2015 and the start of the season for each year (September 1st). The overall model is found to be significant and from the coefficient of determination, 27.8% of the variations in the first difference of the stock index is explained by the variations in the regressors that are stock index, its square, and harvest level for each month and region. Moreover, the logarithmic parameter estimates $\widehat{\zeta_1}$, $\widehat{\zeta_2}$ and $\widehat{\zeta_3}$ are all found to be negative and statistically significant (Table 2.9).

Table 2.9 Parameter Estimates for Stock Index Dynamics

Parameter	Estimate
ζ_1	-1.240***
	(0.216)
ζ_2	-3.637***
	(0.148)
ζ_3	-10.083***
	(0.642)
N	240
R^2	0.278
$F(3, 237)$	30.449***
$\widehat{\bar{K}}$	262993.9

Standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

From the transformations given in (2.30), the estimates for intrinsic growth rate ($\hat{r}$), catchability coefficient ($\hat{q}$), total carrying capacity ($\widehat{K}$), monthly maximum sustainable yield ($\widehat{MSY}$), and stock levels for each month and region can be found (Table 2.10).

Table 2.10 Bioeconomic Parameters

Intrinsic Growth Rate, $\hat{r}$	.2893921
Catchability Coefficient, $\hat{q}$	.0000418
Average Regional Carrying Capacity, $\widehat{\bar{K}}$	262993.9
Carrying Capacity (tons), $\widehat{K}$	1314970
Average Monthly Total Stock (tons)	501086
Average Monthly Harvest (tons)	28691
Maximum Sustainable Yield (tons), $\widehat{MSY}$	95135

Source: Own calculations.

The estimates in Table 2.10 do not contradict comparable findings in the literature. First, the estimate for intrinsic growth rate, $\hat{r}$, is slightly lower than most species-specific prior ranges for r, presented by Demirel et al. (2020). Moreover, the estimate for catchability coefficient is slightly lower than the one found in Zhang & Smith (2011).

The effect of past overfishing is observed in the ratio of the average monthly stock level to the carrying capacity, which is calculated as 38.11%. If this ratio is less than around 50%, the fisheries cannot enjoy maximum sustainable yield, which is approximately $MSY = \frac{rK}{4}$, which is estimated as 95135 tons per month for Turkey. Despite much lower catch levels, 28691 tons per month, than the potential MSY, stock levels seem fluctuating around average between January 2015 and December 2021 (Figure 2.2). As expected, the peak for each year is generally observed during the initial months of each season which is the result of the stock recovery during the fishing ban between April 15th and September 1st. Hence, the troughs are observed at the of the seasons due to the continuous exploitations beforehand.

Figure 2.2 Carrying Capacity, Total Monthly Stock Level and Trends in Stock

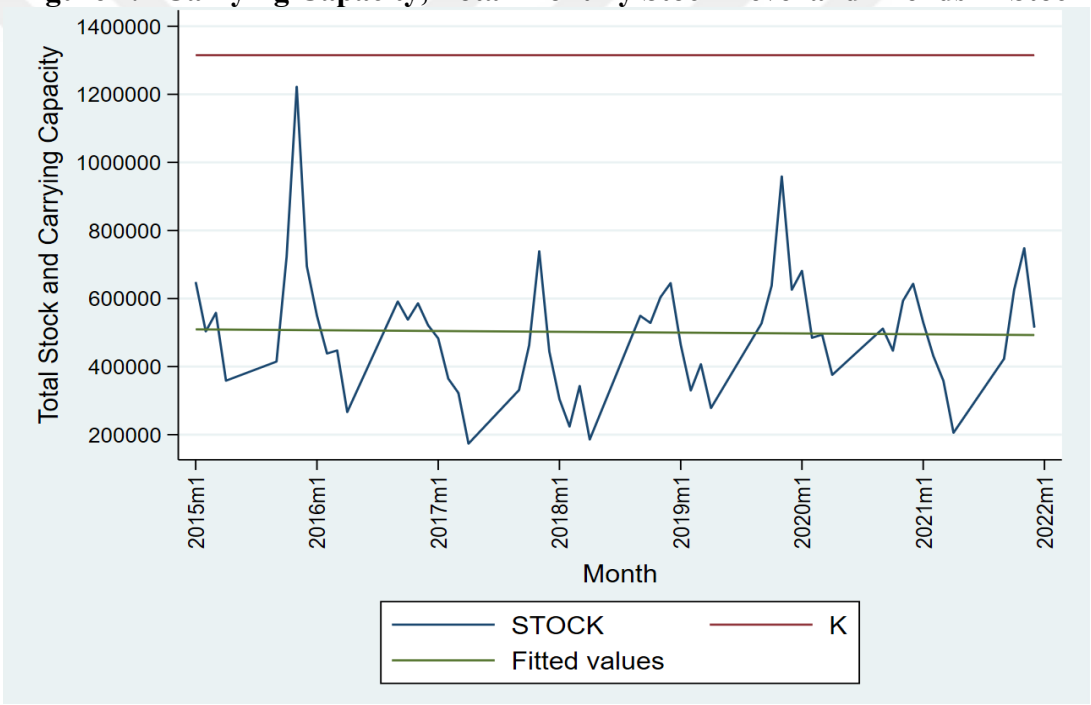


Table 2.11 Regional Average and Volatility of Stock Levels

Region	Average Stock Estimate	Standard Deviation	Coefficient of Variation
Eastern Black Sea	181263	123342.90	0.680
Western Black Sea	216340	107249.60	0.496
Marmara Sea	34480	14967.18	0.434
Aegean Sea	42229	16086.75	0.381
Levantine Sea	26775	10700.94	0.400

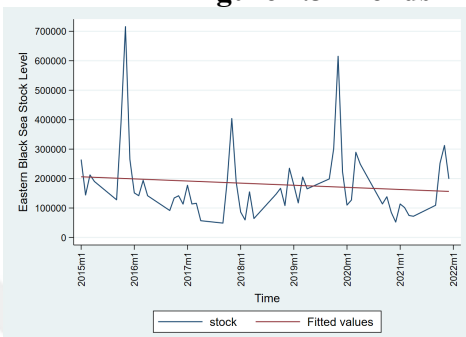
Source: Own calculations.

For a more concentrated fisheries policy, a closer glance at the regional trends in the stock levels is also necessary. In contrast to Marmara, Aegean, and Levantine regions

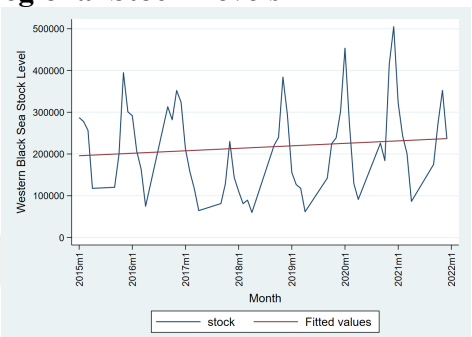
which are associated with low and relatively stable stock levels, The Black Sea is the driving force behind Turkey's fishing industry, contributing to around an estimated 80% of the country's total marine commercial fishing potential. Over 50% of this originates from the Western Black Sea. However, the largest variations in stock levels are observed in the Eastern Black Sea region. In addition, despite being a smaller one, a similar situation is observed in Marmara compared to Aegean Sea (Table 2.11).

Figure 2.3 Trends in Regional Stock Levels

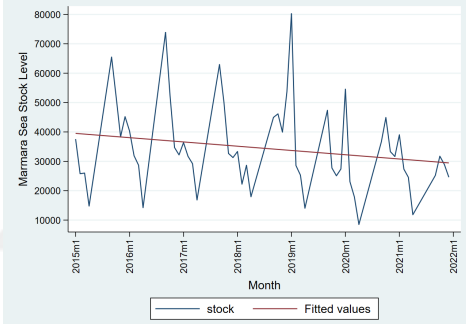
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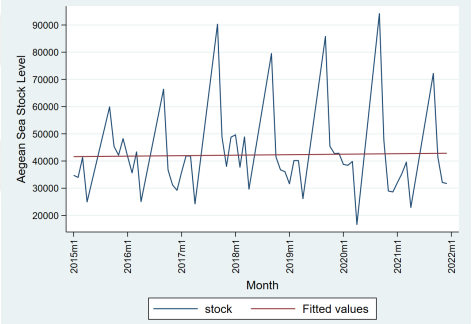
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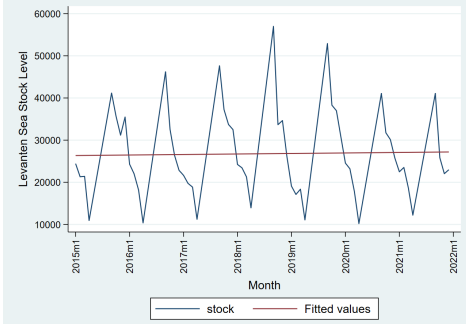
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d



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a – Stock Levels in the Eastern Black Sea
b – Stock Levels in the Western Black Sea
c – Stock Levels in the Marmara Sea
d – Stock Levels in the Aegean Sea
e – Stock Levels in the Levantine Sea

Moreover, as depicted in Figure 2.3, the regions that can be associated with larger variations, namely, the Eastern Black Sea and Marmara Sea, face declining long-term stock levels. On the other hand, the stock levels in other regions seem to compensate these losses.

2.5.2 Stochastic Frontier Model with Inefficiency Effects

After estimating the stock levels for each region and time, these estimates are utilized as the stock variable in the stochastic frontier analysis. Consistent with the theory, harvest is considered as a function of stock and effort in the production frontier (Equation (2.31)). Since the inefficiency effects include many dummy variables, the intercept of this model (η_0) reflects the inefficiency level of the unspecified trawlers in Eastern Black Sea which do not have sonar, echo sounder, cold storage room and generator (Equation (2.32)). The variance of the stochastic error term, σ_v, is considered as a function of the effort level (Equation (2.33)). All the parameters in the error variance function are significant, implying that there is heteroskedasticity in the error term. The parameter estimates of these equations are illustrated in Table 2.12.

The constant term in the frontier function is the natural logarithm of the catchability coefficient as it is previously defined as $q_{SFA} = e^{\vartheta_0}$. As the estimated parameter $\widehat{\vartheta_0} = -6.703$ is statistically significant, the estimate for the catchability coefficient can be calculated as $\widehat{q_{SFA}} = e^{\widehat{\vartheta_0}} = 0.0012272$. This is 29.36 times larger than $\hat{q} = 0.0000418$, which is estimated in the modified generalized fishery model when the stock elasticity is assumed to be 1. In fact, its estimate $\widehat{\vartheta_1} = 0.692$ is significant and lower than one, implying the overestimated catchability in the previous model. Finally, the elasticity of composite effort is estimated as $\widehat{\vartheta_2} = 0.718$. These results imply increasing returns to scale; however, since the control over stock level is limited, it is the only diminishing returns to effort that matters for policies, while diminishing returns to stock is about the long-term recovery.

The inefficiency effects model provides some information about the vessels' distances to the frontier determined by the harvest or the frontier function, based on some of their characteristics. When the size of the η parameters are positive and larger, this implies a larger distance to the frontier, while negative and smaller ones are associated with larger efficiency levels. Accordingly, technical efficiency increases with larger engine power with significant parameter $\eta_1 = -0.046$. As expected, use of either sonar or echo sounder or both lead to efficiency gains by the signs of the associated parameters.

Table 2.12 Stochastic Frontier Model and Inefficiency Effects

Par.	Var.	Est.	Par.	Var.	Est.
Frontier Function			**Inef. Effects Function**		
ϑ_0	Const.	-6.703*** (0.075)	η_0	Const.	1.425*** (0.066)
ϑ_1	$ln(S_{tj})$	0.692*** (0.007)	η_1	$ln(ENGP_{itj})$	-0.046*** (0.011)
ϑ_2	$ln(E_{it})$	0.718*** (0.004)	η_2	$D_{bottomtrawl,itj}$	0.130*** (0.018)
Error Variance Function			η_3	$D_{midwatertrawl,itj}$	-1.061*** (0.024)
π_0	Const.	0.281*** (0.008)	η_4	$D_{purseseine,itj}$	-1.109*** (0.021)
π_1	$ln(E_{itj})$	-0.076*** (0.003)	η_5	$D_{beamtrawl/dredge,itj}$	-1.923*** (0.03)
$E(\sigma_v)$		1.086	η_6	$D_{entanglingnet,itj}$	0.318*** (0.022)
σ_u		0.003** (0.001)	η_7	$D_{surrounding/castnet,itj}$	0.467*** (0.028)
			η_8	$D_{othergear,itj}$	0.451*** (0.033)
			η_9	D_{it2}	0.793*** (0.017)
			η_{10}	D_{it3}	-0.195*** (0.028)
			η_{11}	D_{it4}	0.084*** (0.02)
			η_{12}	D_{it5}	-0.045** (0.022)
			η_{13}	$D_{sonar,itj}$	-0.066*** (0.012)
			η_{14}	$D_{echosounder,itj}$	-0.089*** (0.015)
			η_{15}	$D_{coldstorageroom,itj}$	0.020* (0.012)
			η_{16}	$D_{generator,itj}$	0.010 (0.007)

Standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

Other parameters help us compare gears and regions in terms of technical efficiency, given all other variables are the same. The gears can be ranked in terms of technical efficiency from highest to lowest: beam trawls or dredges, purse seine, midwater trawl, bottom trawl, entangling net, and surrounding or cast net. Similarly, regions can be ranked as: Marmara, Levantine, Eastern Black Sea, Aegean, and Western Black Sea.

Figure 2.4 Declining Trend in Fisheries Efficiency

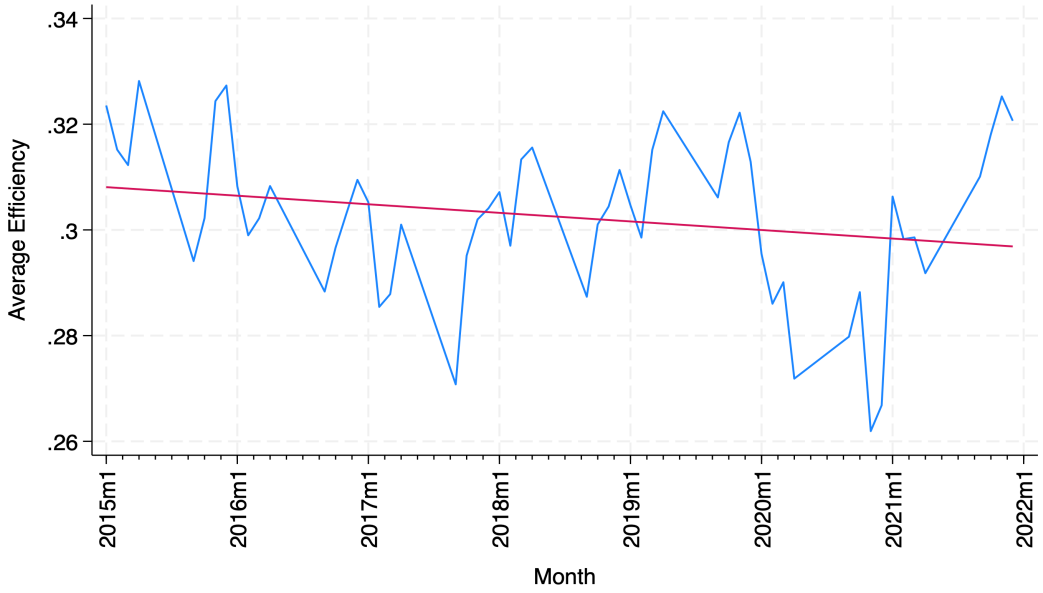
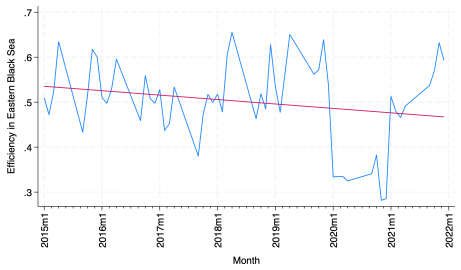
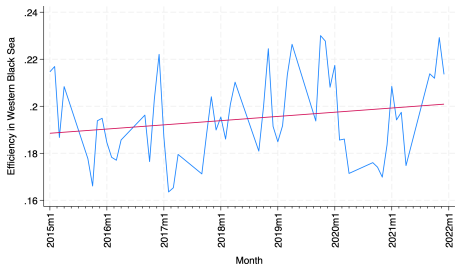


Figure 2.5 Regional Trends in Fisheries Efficiency

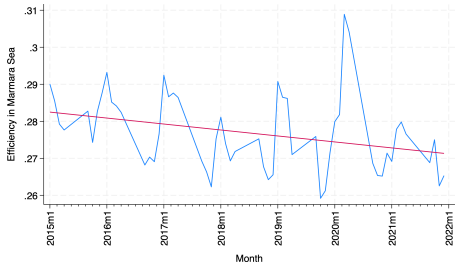
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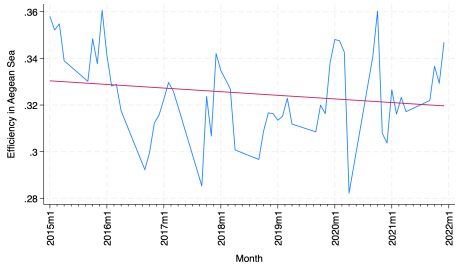
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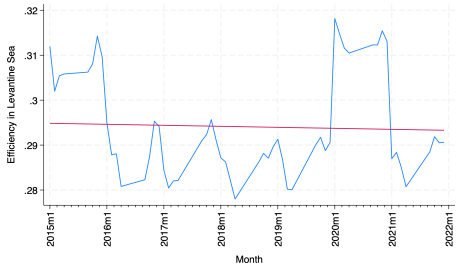
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a – Stock Levels in the Eastern Black Sea
b – Stock Levels in the Western Black Sea
c – Stock Levels in the Marmara Sea
d – Stock Levels in the Aegean Sea
e – Stock Levels in the Levantine Sea

When the observation level efficiencies are estimated by Jondrow, Lovell, Materov, Schmidt (JLMS) estimator, (Jondrow et al., 1982; Kumbhakar et al., 2018), and their

geometric means are obtained, it can be observed that there is a long-term declining trend in the efficiency levels in Turkish coasts (Figure 2.4).

If the aggregate monthly efficiency levels are disaggregated into regions, it can be observed that there are significant efficiency gains in the Western Black Sea, while others contribute to the overall decline (Figure 2.5). For Black Sea and Marmara regions, these trends are in line with the trends in the stock levels. In other words, there are declining stocks in Eastern Black Sea and Marmara Sea, just as the average inefficiencies. Similarly, the fishing units in Western Black Sea enjoy the efficiency gains probably due to the increasing stocks.

2.6 Discussion

Although some of the stock levels and trends estimated in the present study seems to contradict the results in Demirel et al. (2020) that assess relatively higher stock levels and long-term declines in the most stocks, the two studies differ in their methodology, data set, and aims. Demirel et al. (2020) estimate biomass dynamics based on a CMSY method with the long-term species-specific time-series catch and resilience data as well as prior estimates for intrinsic growth and stock-to-capacity ratios. On the other hand, the generalized fishery model in this study aggregate firm-specific catch, effort, and other technical capabilities covering large-scale fishing units to estimate them. Finally, while their study aims at presenting detailed stock assessments for numerous species, this study aggregates them for a predetermined group to make a general evaluation for economics of fisheries regulations.

One reason for this difference may be due to the differing scopes of the data sets. Since the catch levels of small-scale fishing units are excluded and larger-scale fishing units are subject to seasonal closures, the monthly stock dynamics in this study are determined by lower catch levels, resulting in both smaller stock estimates and less variations in stocks. Another difference is that this study covers a relatively shorter and recent period, during which Turkish fisheries are more regulated. Only the last three years in the data set employed by Demirel et al. (2020), which constitute 6% of observations, is the first three years of the data set in this study out of seven. Though it seems that their study is sounder in terms of length of times series suggested as at least 15 years (Kokkalis et al., 2024), the monthly panel structure of the present study satisfies adequate number of observations.

A similar contradiction in the literature presented by (Zhang & Smith, 2011) can help explain this difference. With the same data set, they have compared the results of the standard Gordon-Schaefer with the generalized fishery model they have suggested. They have found a lower maximum sustainable yield and a larger intrinsic growth rate using the generalized fishery model than the standard level. They have demonstrated that the standard model and its extensions like CPUE and CPUE-like estimators lead to biased results overestimating the stock levels.

They have also argued that although the generalized model resembles approaches employing CPUE-like proxies, it possesses advantages including more comprehensive micro-level information, allowing to quantify variations in the stock index, and easing of computational burden. Although their arguments do not directly contradict the CMSY methodology, as it is also based on CPUE proxies where stock assessments are not present, they cannot explain the distinctions between the results of Demirel et al. (2020) and the present study. Still, despite the differences in the stock size and trends, the policy implications regarding the resource conservation are in alignment, requiring strong reduction of the fishing pressure in Turkish marine fisheries.

Moreover, the set of analyses presented in this study aims at combining estimation of bioeconomic parameters and inefficiency effects in order to examine the trends in the dynamics in stock levels, technology use, and technical efficiency. Most of the previous studies listed in the literature review have ignored the impacts of stock dynamics on the levels and determinants of productivity in fisheries due to lack of relevant data except Kirkley et al. (1995), Dresdner et al. (2010), Duy & Flaaten (2016) and Pascoe & Herrero (2004). Moreover, the main issues in the proposed methods for stock estimation do not include possible inefficiency component of the catch activities. The results in this study demonstrate that both analyses should be considered together in order to obtain more realistic parameters and overcome the computational problems in the analyses.

Finally, the technical efficiency analyses conducted in Turkey cover a specific region, species, or a determined fishing group (Ceyhan & Gene, 2014; Dağtekin et al., 2021, 2022; Tunca et al., 2021). On the other hand, this study covers entire country allowing for an analysis of five fishing regions. In addition, as pointed out Kumbhakar et al. (2018), a two-step methodology that that estimates efficiency scores in the first step, then estimates determinants of efficiency in the second, results in biased parameters,

suggesting methods that simultaneously estimate factors of efficiency. Thus, this study employs one of the most desirable methods allowing for panel data; namely, a stochastic frontier model with inefficiency effects, proposed by Battese & Coelli (1995).

2.7 Conclusion

In order to develop more effective policies to acquire more efficient, optimal, and sustainable fisheries in Turkey, and overcome the negative impacts of climate change, overfishing, and technological developments, the current state of the stock dynamics and the impact of unit characteristics must be known. By applying a combination of modified and previously suggested methods, this study provides both methodological enrichment and valuable insights for the design of fisheries policy.

The regionally disaggregated analysis underlines the importance of adapting suitable policies for distinct ecological, political, and economic conditions of each region. The marine areas where significant biomass losses occur should be protected more intense regulations. Exclusively, for the Marmara Sea, the environmental conditions must be enhanced through more effective waste management rules and marine traffic rules. In addition, the fishing season should be shortened for both environmental considerations and stock recovery in this region.

For the Eastern Black Sea, an introduction of the individual transferable quotas should be applied for some commercially valuable species in order to reduce the fluctuations in the catch levels and stock recovery of essential species like anchovy. Finally, for all regions, the intense use of environmentally undesirable gear types and negative externalities arise from fisheries technology should be examined and a framework to reduce their adverse effects should be formed.

While this study offers significant insights for fisheries policy, there remain numerous unresolved inquiries. Firstly, it is important to analyze the relatively low levels of effort in the Levantine Sea, despite its extensive coastline. Furthermore, it is necessary to formalize the underlying causes for the low catch per unit effort in the Aegean Sea. Especially, the potential external effects of marine aquaculture on catch levels, the market dynamics between two seafood sources, and the input-output interaction between them are crucial for ensuring the sustainability of fisheries and food security.

Finally, an additional area of future research could involve investigating the effects of climate change and municipal waste on marine ecosystems and fisheries.

3 CENSORING, ENDOGENEITY, AND DEMOGRAPHIC SCALING IN MULTI-STAGE DEMAND SYSTEMS: AN APPLICATION FOR TURKISH SEAFOOD MARKET

3.1 Introduction

Seafood consumption in Turkey presents an interesting case as it can be anticipated that it is vital for Turkish people who live on a giant peninsula. However, contrary to world averages, recent data illustrates that it is less popular than poultry and red meat (TEPGE, 2020; OECD, 2020; FAO, 2020). Table 3.1 presents the annual per capita consumption of animal meat (Kg) for Turkey and the world.

Table 3.1 2020 Annual Per Capita Consumption (Kg)

	Turkey	**World**
Beef and Veal	9.6	6.4
Sheep	4.2	1.8
Poultry	19.2	14.9
Pork	0	10.7
Seafood	6.7	20.2

Sources: TEPGE, OECD, FAO

However, it is unclear why individual food preferences in Turkey are not directed to seafood as much as others despite its role as a vital source of protein and essential nutrients like omega 3. Moreover, from expanding aquaculture production, seafood has been one of the fastest-growing food sectors in recent years. Turkey's aquaculture production is also experiencing a steady and continuous increase, mirroring the global trend. Additionally, the proportion of aquaculture in the overall production is on the rise.

Since 2003, the Ministry of Agriculture and Forestry's support for aquaculture development significantly contributes to this growth. In 2022, financial assistance of 0.75 Turkish Lira per kilogram was given for the purpose of supporting trout breeding. Similarly, a support of 1.50 Turkish Lira per kilogram was provided for the breeding of new species and for closed system production. Carp production received a support of 0.50 Turkish Lira per kilogram, while mussel production received a support of 0.10 Turkish Lira per kilogram. Furthermore, disease-free hatchery breeding trout support

were offered at a cost of 60 TL per piece. In 2022, the Ministry of Agriculture and Forestry provided around 88 million TL in financial assistance to aquaculture producers. 93% of the total support payment was allocated specifically for trout support (Çöteli, 2023).

Table 3.2 Net Domestic Availability

Year	**2019**	**2020**	**2021**
Marine Catch	428.7	328.5	293.7
Aquaculture	373.4	421.4	471.7
Imports	337.2	318.5	322.7
FMFO Imports	244.2	230.3	216.5
Total Exports	218.8	228.9	249.3
Sales to FMFO Factories	247.2	134.0	138.3
Other Intermediates	32.7	29.3	25.4
Net Domestic Consumption	396.4	445.9	458.6

Sources: TurkStat MEDAS, FAO

More abundant seafood is expected to result in its increasing consumption. However, several reasons may slow down this abundance. To clarify, seafood from different sources including marine catch, aquaculture production, and imports are reduced by exports and input use of seafood such as direct sales to fishmeal and fish oil factories, other intermediate use of captured fish, and high share of imports unfit for human consumption, mainly fishmeal and fish oil (Table 3.2). For example, only around 400 out of 1100 thousand tons of seafood were available for final consumption in 2019 although this rate has a declining trend in the next two years.

Moreover, Turkey's exports of aquaculture products have experienced a substantial growth in recent years, in tandem with advancements in production and processing technologies. More specifically, although it seems beneficial for national accounts, around 100 thousand tons of net seafood exports contribute to this gap, following the high-level use of fish meal and fish oil in aquaculture production (Table 3.3). The fact that most of the exported products include cultured seabream, seabass, and trout, which are available for final consumption, and most of the imported are fishmeal and fish oil, that are the most important inputs to produce these types of cultured seafood, the rise in the available seafood for domestic consumption remains limited.

Table 3.3 Foreign Trade (Tons)

	Year	2019	2020	2021
Exports	**Seabream**	60775	63106	71486
	Seabass	49314	45434	48637
	Trout	27398	36023	50564
	Nei	28252	28140	36061
	Fish meal and fish oil	18860	26048	9455
	Tuna	11150	11936	14280
	Others	10100	10017	10656
	Carps, eels, snakeheads	7724	3291	2898
	Mollusks	3197	2646	2466
	Anchovy	2016	2282	2846
	Total	218785	228923	249348
	FMFO Excluded	199925	202875	239893
Imports	**Fishmeal and fish oil**	244231	230285	216533
	Mackerel	26715	22096	36443
	Tuna	23283	28272	32580
	Sardine	14996	17321	18580
	Others	9584	6826	4941
	Salmon	5653	4058	6054
	Saithe (pollock)	4641	3722	1086
	Cuttlefish and squid	3423	1989	2848
	Anchovy	2535	2719	1728
	Shrimps and prawns	2131	1195	1921
	Total	337193	318483	322715
	FMFO Excluded	92962	88198	106182
Net	**Net Exports**	-118407	-89560	-73367
	Net Exports (FMFO Excluded)	106964	114677	133711

Source: FAO

In addition to the considerations in other disciplines like environment, ecosystem management, and health and nutrition, this issue also has implications for regional economic policy and development, consumer behavior, and trade. Despite these, economists have not adequately addressed the Turkish seafood market, which is associated with gastronomic traditions shaped around the Mediterranean and Black Sea marine ecosystems and many inland waters.

Although some demand studies classify fish as a distinct food group, the literature still lacks a particular analysis of Turkish seafood demand. One reason may be the small share of seafood consumption in total food expenditures. Fortunately, some available methods can be applied for a group of small consumption. This study aims to fill this gap by applying a multi-stage budgeting approach based on a series of system of equations analyses. This approach can be applied by many studies in numerous ways depending on the number of stages, choice of the model specification, choice of the food groups, consideration of censored dependent variables, the inclusion of quality-adjusted prices, and the inclusion and form of demographic characteristics.

This study applies a unique but simple multi-stage budgeting approach combining TurkStat's Household Budget Survey 2003 (HBS2003) data set, a series of quadratic almost ideal demand system (QUAIDS) analyses, correction for censored dependent variables, and demographic scaling. Although HBS2003 is a popular data set in the literature due to the detailed information on prices, expenditure shares, and household characteristics, it has not been used for a particular analysis of seafood demand. Moreover, the demand studies using this data set ignore the possible quadratic relationship between the expenditure shares and deflated expenditures. Although a correction for zero expenditures can be found in most demand studies regardless of the choice of the data set, the demographic scaling technique that forms relationships between elasticities and demographic variables is not as popular as the one called demographic translation, which just adds demographic variables as an additional explanatory variable into the expenditure-share equations. In fact, a combination of demographic scaling and consideration of censored dependent variables is absent in seafood demand studies.

Besides, in contrast to the popular approach that ignores expenditure-saving decisions in multi-stage budgeting, this study uniquely highlights its importance by adding another stage to the core of the analysis. Since households do not have control over prices, income, and demographic characteristics in cross-sectional data, this study argues that their first decision is how much to spend or save. If the households are assumed to directly allocate their income to food and other expenditures, the outcomes will be misleading as there are not only households that do not spend all their income, but also the ones that make negative savings. If they are directly assumed to allocate their total expenditures to food and others, there is endogeneity in the equations

because the unobserved error terms including omitted income will be correlated to total expenditures. As a result, this endogeneity will be transferred to consecutive stages, leading to inconsistent results. This problem is handled in the first stage, where the first predicted values are obtained and used in the second stage as an instrument. The same approach is applied until the last stage.

The following two sections summarize the related literature and explain the methodology. Section 3.4 presents the data and descriptive statistics of associated variables. The last section concludes after the results presented in Section 3.5.

3.2 Literature Review

The extensive literature on food demand analysis includes various approaches for most geographic regions, some demographic segments, food groups, data types, and methods. The diversity of methodological approaches has led to the widespread emergence of this prevalent issue in academic studies. Okrent & Alston (2011) comprehensively reviewed the approaches employed in food demand studies and listed some approaches consistent with the demand theory, including their advantages and disadvantages.

One popular approach is the linear expenditure system (LES) (Klein & Rubin, 1947), which suggests utility maximization subject to budget constraints. However, it is very restrictive as it imposes that all goods must be normal and substitutes for each other. Moreover, it allows for only linear Engel curves, which may not be empirically adequate. Recently, Bronnmann et al. (2019) employed LES in the first stage of their analysis, exposing their results to its pitfalls.

Another approach is to define an indirect utility or expenditure function to acquire a demand function. One of the most popular methods that employ this approach is the indirect translog (ITL) (Christensen et al., 1975) and its extension to generalized translog (GTL) (Pollak & Wales, 1992) demand systems. They obtain the Marshallian demand by transforming an indirect utility function that can be reduced to Cobb-Douglas form under certain assumptions. However, despite their flexibility compared to LES, they present no developed method for the direct effect of demographic variables on elasticities. Yen et al. (2004) employed a translog demand system

accounting for zero expenditures. They added all related demographic variables as explanatory variables for the demand equations.

More related to the present study, Deaton & Muellbauer (1980) proposed a more flexible approach called “almost ideal demand system (AIDS)” by defining an expenditure function consistent with price-independent generalized logarithmic (PIGLOG) preferences. Although it had complications in its initial settings, many extensions have been proposed to overcome them. First, Deaton & Muellbauer (1980) proposed a linear approximation to the transcendental logarithmic (translog) price index using the Stone index to reduce computational complexity. However, this convenient and popular approach may be misleading.

Moschini (1995) pointed out that the Stone price index does not meet the commensurability property. In other words, as it depends on expenditure shares, the Stone index does not remain constant as measurement units of goods change. Thus, they suggest discarding the LA/AIDS model in favor of the original one or using the Tornqvist index, log-linear analogs of the Paasche or Laspeyres index, or geometrically weighted average prices using base shares. Additionally, recent developments in computational power have made such a practice obsolete. Despite these issues, the Stone index applications remained very popular in the literature. For example, Armagan & Akbay (2008) examined the demand for animal products by utilizing the LA/AIDS model based on the Stone index.

Then, Ray (1983) proposed another method for incorporating demographic variables into the household demand analysis, ensuring that the equivalence scale is consistent with the demand theory. Besides, since they have also used the expenditure function to derive the equivalence scale, it could easily be incorporated into the AIDS framework. By this method, the elasticities and parameters of the demand system are rescaled according to the demographic characteristics.

In contrast, as a more popular method proposed by Pollak & Wales (1978), demographic translation results in shifts in the expenditure-share equations by the translation parameters without suggesting a direct effect of demographic characteristics on the elasticities. Both methods have their own strengths and weaknesses. Moreover, to its interpretive advantage, the scaling technique internally adjusts the price index and price aggregator according to demographics. Nevertheless, it is highly dependent on the use of continuous demographic variables. On the other

hand, any demographic variable can be considered by employing the translation technique; however, its interpretation remains descriptive. Still, the scaling technique could not be as popular as the translation that almost all studies favor. All reviewed studies except Kimsanova et al. (2023) applied the demographic translation technique.

For many observations, most cross-sectional data sets suffer from zero expenditure shares and associated missing prices, leading to censored dependent variables in any approach to demand system analysis. Heien & Wessells (1990) suggested a two-step methodology by incorporating inverse Mill's ratio (IMR) as an additional explanatory variable into the expenditure-share functions to handle censored dependent variables. Later, Shonkwiler & Yen (1999) suggested a similar but more efficient method for the same purpose, claiming that Heien and Wessels' technique is analytically incorrect and performs inadequately in Monte Carlo simulations. Both methods were based on estimating probability and cumulative density functions by applying a probit or Tobit model in the first stage and modifying expenditure-share equations in the second using those functions.

A hedonic price function is frequently estimated in the literature to handle missing prices. However, as most cross-sectional data sets do not present characteristics of consumer products, several demographic characteristics are used to estimate such a function. Then, missing prices are replaced with the estimated constant term, while observed prices are replaced with the sum of the constant and error terms (Akbay, 2007; Bronnmann et al., 2016). However, such a practice unnecessarily changes the observed prices. Instead, Dey (2000) used regional averages for missing prices. This is empirically more practical and reliable because the observed prices remain unchanged, and it can easily be assumed that households face prices and are unwilling to pay them. Furthermore, demographic characteristics do not necessarily give true information about the prices paid.

Banks et al. (1997) revealed another flaw in the AIDS model. They stated that consumption data generates Engel curves that are more nonlinear than the AIDS model allows. They extended the AIDS to include quadratic Engel curves by defining an indirect utility function of another form, which they named quadratic AIDS (QUAIDS). Later, Poi (2002) suggested a method for incorporating Ray's demographic scaling into the QUAIDS framework.

In addition to these theoretical developments in demand system analysis, a frequently observed distinction among studies is their assumed budgeting processes. Some studies have relied on an incomplete demand system in a single stage. Akbay (2007) examined oil and fat demand by allowing consumers to allocate their expenditures to the products in question. They employed an LA/AIDS model by approximating the translog price index with the Laspeyres, as suggested by Moschini (1995). Similarly, Bilgic & Yen (2014) applied the LA/AIDS model to analyze the demand for animal food, and Bronnmann et al. (2016) and Toufique et al. (2018) applied QUAIDS to seafood demand. Even though Some Turkish food demand studies have categoriz

On the other hand, some studies employed complete demand systems with a single budget or multi-stage budgeting. Yen et al. (2004), Akbay et al. (2007), Bilgic & Yen (2013), and Kimsanova et al. (2023) have analyzed seafood demand by directly allocating income, total expenditure, or total food expenditure to all determined food aggregates. Although these single-stage approaches provide valuable insights into the food demand analysis, they both have limitations. While the single-stage incomplete demand systems ignore the effects of other expenditure decisions on their focus food group, its complete counterpart cannot practically provide disaggregated analyses of specific foods. Thus, a multi-stage complete demand analysis would solve these limitations.

Strotz (1957) pioneered the idea of a utility tree. Following Gorman (1959) and Strotz (1959), the strong definition of separability, requiring the marginal rate of substitution (MRS) between two subgroups of a group to be independent of the total consumption of other groups, is replaced by a weak separability assumption, by which the MRS between two subgroups of a group is independent of the individual consumption of other groups. To clarify, while strong separability dictated constant total budgets within each group, leaving the utility tree obsolete, weak separability allows for budget changes in every stage, allowing for various multi-stage scenarios.

Based on the weak separability assumption, several studies can be reviewed focusing on seafood demand, from major food groups to various types of seafood in a few stages. Dey (2000), Garcia et al. (2005), Dey et al. (2008), and Dey et al. (2011) examined demand for seafood by applying similar procedures. In the first stage, they employed ordinary least squares (OLS) to make an allocation of expenditures between food and nonfood expenditures. In the second stage, they applied AIDS to allocate

food expenditures to broad categories. Finally, QUAIDS is applied to allocate one of the broad categories, seafood expenditures, to different seafood types. One problem in their approach was that they evaluated Moschini's criticism as it only applies to LA/AIDS, so they utilized Stone's prices index in the third stage (Dey et al., 2008). However, the unit of measurement effects would distract not only LA/AIDS but also QUAIDS in their applications.

Aung et al. (2022) explained the reason for using the predicted values in subsequent stages. In general, the observed separable group expenditures under multistage budgeting cannot be considered exogenous, as the error term in the budget equation is an exact linear combination of the residuals of unconditional demand (Lafrance, 1991). This problem can be handled by defining appropriate instruments for expenditure variables, following Edgerton (1993), demonstrating that instrumental variable estimation in nonlinear demand systems produces consistent results. That is, the predicted values in each stage act as an instrument for the expenditure variables in another stage.

Table 3.4 summarizes the reviewed studies most related to the present one. Yen et al. (2004) and Kimsanova et al. (2023) present relatively rare applications for translog demand systems and QUAIDS with demographic scaling, respectively. Four of them utilized the exact same data set as the present study (Akbay et al. (2007); Akbay (2007); Bilgic & Yen (2013); Bilgic & Yen (2014)). Armagan & Akbay (2008) is another study conducted in Turkey using other survey data. Finally, the remainder of the studies target seafood demand in their analyses. Furthermore, all studies are evaluated by seven main methodological aspects they utilized and noted in the table.

This study aims to apply a unique combination of the multi-stage approaches listed. First, it considers households' expenditure-saving decisions as their initial decision, claiming it is the ultimate control for endogeneity. More precisely, each household is assumed to be a price-taker of its chosen commodity bundles and sub-bundles.

Although they can switch between specific goods within the commodity groups based on their current conditions and preferences, once they have obtained sufficient price information, they have chosen to make the expenditure or not on the related bundles. Thus, they only have the power to adjust their expenditure shares. Moreover, they cannot quickly adapt their income and demographic characteristics in a static analysis. As a result, while all composite prices, household income, and demographic variables

are assumed to be strictly exogenous, their total expenditures, food expenditures, and all expenditures to the subgroups and associated expenditure shares are endogenous.

Table 3.4 Summary of Methodologies in the Reviewed Literature

Author (Year)	Init.	Budgeting	Models	Cens.	Dem.	Price index
Dey (2000)	TE	Multi-stage, complete	OLS, AIDS, QUAIDS	Tobit	T.	GWMP, Stone
Yen et al. (2004)	TFE	Single-stage, complete	ITL	SY99	T.	
Garcia et al. (2005)	TE	Multi-stage, complete	OLS, AIDS, QUAIDS	Tobit	T.	GWMP, Stone
Akbay et al. (2007)	Income	Single-stage, complete	LA/AIDS	SY99	T.	LP
Akbay (2007)	Related	Single-stage, incomplete	LA/AIDS	SY99	T.	LP
Dey et al. (2008)	TE	Multi-stage, complete	OLS, AIDS, QUAIDS	Tobit	T.	GWMP, Stone
Armagan & Akbay (2008)	Related	Single-stage, incomplete	LA/AIDS	None	T.	Stone
Dey et al. (2011)	TE	Multi-stage, complete	OLS, QUAIDS	HW90	T.	GWMP, Stone
Bilgic & Yen (2013)	TFE	Single-stage, complete	LA/AIDS	SY99	T.	LP
Bilgic & Yen (2014)	TE	Single-stage, incomplete	LA/AIDS	Bayes.	T.	GWMP
Bronnmann et al. (2016)	Related	Single-stage, incomplete	QUAIDS	SY99	T.	TL
Toufique et al. (2017)	Related	Single-stage, incomplete	QUAIDS	None	T.	TL
Bronnmann et al. (2018)	Income	Multi-stage, complete	LES, QUAIDS	SY99	T.	TL
Aung et al. (2022)	TE	Multi-stage, complete	OLS, QUAIDS	HW90	T.	Stone
Kimsanova et al. (2023)	TFE	Single-stage, complete	QUAIDS	None	S.	TL

TE: Total expenditure, TFE: Total food expenditure, Related: Total expenditure on the related goods, OLS: Ordinary least squares, LES: Linear expenditure system, ITL: Indirect translog demand system, TL: Transcendental Logarithmic, SY99: Shonkwiler and Yen (1999), HW90: Heien and Wessels (1990), Dem.: Demographic, T.: Translation, S.: Scaling, LP: Laspeyres, GWMP: Geometrically weighted mean of price.

Another unique aspect of the study is that it combines Ray's demographic scaling technique, a consideration of censored dependent variables, and QUAIDS in the subsequent analyses. To this end, instead of relying on a linear approximation to the nonlinear price index, original transcendental logarithmic price index is employed.

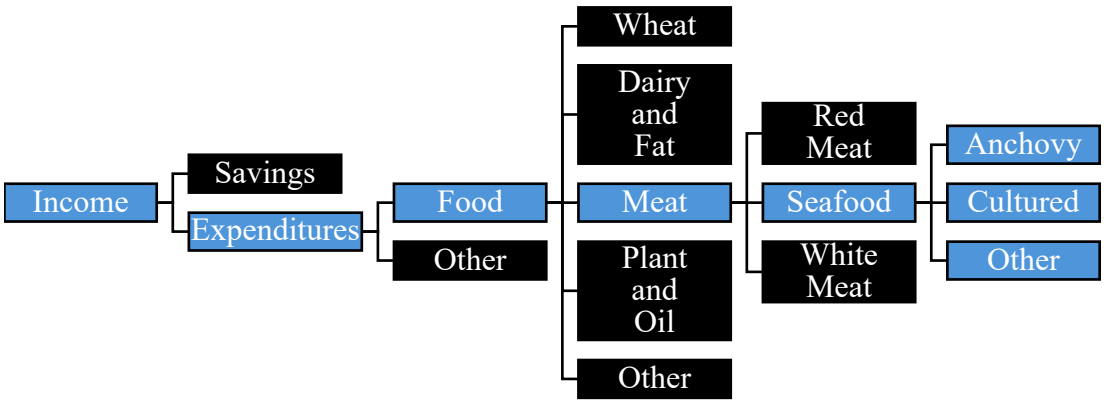
Furthermore, while missing prices are replaced by the regional averages, life quality as a demographic variable is constructed by the predicted values of the rental value of the house lived, defined as a function of the house characteristics, like the idea of quality-adjusted prices. Another interesting demographic variable is households' ability to meet their basic needs, which is a ratio of household income to the minimum required income to meet their basic needs.

3.3 Methodology

3.3.1 The Approach and Assumptions

This study employs a multi-stage budgeting methodology to investigate household spending patterns, specifically on seafood demand. As illustrated in Figure 3.1, some choices are offered to households at every stage, and they are required to distribute their available resources among these options, considering their income, the prices they encounter, and their individual characteristics. First, they determine the income they wish to spend and save. Once they allocate their spending between food and other goods, they categorize their intake of animal meat separately from the other four food groups, then their consumption of seafood separately from red meat (bovine and ovine) and white meat (poultry). Finally, they choose the type of seafood they will consume.

Figure 3.1 Classification in Each Stage



It is necessary to make certain additional assumptions to estimate the demand systems using this methodology. First, every household is assumed to be a price taker for their own commodity bundles and sub-bundles. With adequate price information, they have decided whether to spend on the associated bundles, even though they can switch between goods within commodity groups based on their current circumstances and preferences. Their authority is just limited to modifying quantities and allocations of

expenditures. Furthermore, they cannot rapidly adjust their income and demographic characteristics in a static analysis. Consequently, it is assumed that every demographic variable, composite price, and household income is strictly exogenous. Furthermore, it is assumed that the utilities acquired from the commodity bundles at each stage can be isolated. Weak separability implies that the marginal rate of substitution between any two commodities within a given group is independent of the consumption level of goods outside that group. The multistage budgeting allows for embedding the impact of other goods in the previous stages.

Another benefit of applying a multi-stage budgeting approach is that it allows for the use of appropriate instruments to eliminate the endogeneity of expenditure variables. In general, the observed separable group expenditures under multistage budgeting cannot be considered exogenous as the error term in the budget equation is an exact linear combination of the residuals of unconditional demand (Lafrance, 1991). This problem can be handled by defining appropriate instruments for expenditure variables following Edgerton (1993), showing instrumental variable estimation in nonlinear demand systems produces consistent results. The present study estimates least squares regressions in each stage to obtain fitted values for the related expenditures that are used as instruments in the following stages.

3.3.2 Development of the Model

3.3.2.1 Initial Stages

If a decision maker or a consumer has a finite number of options available for resource or expenditure allocation, the number of decisions required will equal the number of possibilities minus one. In essence, assigning the remaining resource to the last option is not a matter of choice but an unavoidable outcome. In Stage 1, as the households allocate their income only to spending and saving, estimating one equation to understand the decisions is sufficient. Inasmuch as the fitted values for the total expenditures are necessary for the next stage, the logarithmic total expenditure, $ln(E_h)$, of each household h is defined as a function of logarithmic income, $ln(I_h)$, logarithmic food price level $ln(P_h)$, which is a proxy for the overall price level that each household face, and four demographic characteristics (D_{hk}), including household size (D_{h1}), life quality (D_{h2}), ability to meet basic needs (D_{h3}), and restaurant, tobacco, and alcohol (RTA) expenditures (D_{h4}).

$$ln(E_h) = \theta_{0_1} + \theta_{1_1} ln(I_h) + \theta_{2_1} ln(I_h)^2 + \theta_{3_1} ln(P_h) + \sum_{k=1}^{4} \tau_{k_1} D_{hk} + u_{h_1} \quad (3.1)$$

With average income elasticity of expenditure, $\mu_I = \frac{1}{n}\sum_h \left(\theta_{1_1} + 2\theta_{2_1}\right) \frac{ln(I_h)}{ln(E_h)}$, uncompensated price level elasticity $\mu_{UP,1} = \frac{1}{n}\sum_h (-1 + \theta_{3_1}(\frac{ln(P_h)}{ln(E_h)}))$, and compensated price level elasticity, $\mu_{CP,1} = \frac{1}{n}\sum_h (-1 + \mu_{UP,1} + \mu_I \frac{ln(E_h)}{ln(I_h)})$.

After the least squares estimation is conducted, predicted values are obtained and instrumented in the second stage, as the total expenditure is correlated with its predicted variable, and the predicted variable is uncorrelated with the error term in the second equation. The logarithmic food expenditure, $ln(F_h)$, as a function of $\widehat{ln(E_h)}$, its square, $ln(P_h)$, and demographic variables is estimated:

$$ln(F_h) = \theta_{0_2} + \theta_{1_2} \widehat{ln(E_h)} + \theta_{2_2} \widehat{ln(E_h)}^2 + \theta_{3_2} ln(P_h) + \sum_{k=1}^{4} \tau_{k_2} D_{hk} + u_{h_2} \quad (3.2)$$

Then, the elasticities are computed with the same procedure above, and the predicted values, $\widehat{ln(F_h)}$, are stored for the next stage.

3.3.2.2 Almost Ideal Demand System (AIDS)

Starting from the third stage, censored quadratic almost ideal demand systems with demographic scaling are estimated for five main nutritional groups (N), four animal meat groups (M), and five seafood groups (S). Historically, the almost ideal demand system (AIDS) model, introduced by Deaton & Muellbauer (1980), is one of the most popular systems of demand equations. AIDS is based on the notion of "price-independent generalized log-linear (PIGLOG)" preferences, which satisfies the conditions required for exact aggregation of consumer behavior. Thus, the market demand can be depicted as if it were the result of the decisions made by a rational representative consumer. Essentially, once the preferences are defined in this form, the aggregated data from different consumers can be used to estimate the market demand that satisfies the theoretical conditions. Without disturbing the ordinal utility concept,

the logarithm of PIGLOG-class expenditure, $lne(u, \boldsymbol{p})$, as a function of utility (u) and price vector ($\boldsymbol{p}$) can be defined with a few modifications:

$$lne(u, \boldsymbol{p}) = (1 - lnu)lna(\boldsymbol{p}) + lnu\big(lna(\boldsymbol{p}) + b(\boldsymbol{p})\big) \tag{3.3}$$

where the price index $lna(\boldsymbol{p})$ is defined in transcendental logarithmic form:

$$lna(\boldsymbol{p}) = \alpha_0 + \sum_i \alpha_i \, lnp_i + 0.5 \sum_i \sum_j \gamma_{ij} lnp_i \, lnp_j \tag{3.4}$$

and the price aggregator $b(\boldsymbol{p})$ is:

$$b(\boldsymbol{p}) = \prod_i p_i^{\beta_i} \tag{3.5}$$

If $lnu = 0$, the household lives in a subsistence level and $lna(\boldsymbol{p})$ is the level of subsistence expenditure. On the other hand, if $lnu = 1$, maximum life satisfaction is attained, and $b(\boldsymbol{p})$ is the minimum cost of bliss. Therefore, it is appropriate to define α_0 as the natural logarithm of the minimum level of expenditure in the data set (StataCorp, 2023).

The expenditure share function for good i, w_i, can be acquired from Equation (3.3). For $m = e(u, \boldsymbol{p})$, Equation (3.3) can be rewritten as $lnu = \frac{ln\left(\frac{m}{a(\boldsymbol{p})}\right)}{b(\boldsymbol{p})}$. Moreover, as the Hicksian demand for good i is $h_i(u, \boldsymbol{p}) = \frac{\partial e(u,\boldsymbol{p})}{\partial p_i}$, the expenditure share can be written by $w_i = \frac{p_i h_i(u,\boldsymbol{p})}{e(u,\boldsymbol{p})} = \frac{p_i \partial e(u,\boldsymbol{p})}{e(u,\boldsymbol{p}) \partial p_i} = \frac{\partial lne(u,\boldsymbol{p})}{\partial lnp_i}$. Thus, the expenditure share equation for good i, w_i, can be found as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} lnp_j + \beta_i ln\left(\frac{m}{a(p)}\right) \tag{3.6}$$

Here, the value of β_i determines the relationship between expenditure shares and deflated expenditure, $\frac{m}{a(p)}$. A positive β_i implies that the good i is a normal good.

3.3.2.3 Demographic Scaling

Later, Ray (1983) proposes demographic scaling technique defining the general equivalence scale, $d_0(u, \boldsymbol{p}, \boldsymbol{z})$, and extending the expenditure function with it.

$$e^d(u, \boldsymbol{p}, \boldsymbol{z}) \;=\; d_0(u, \boldsymbol{p}, \boldsymbol{z}) e(u, \boldsymbol{p}) \tag{3.7}$$

The equivalence scale is decomposed as

$$\begin{gathered} d_0(u, \boldsymbol{p}, \boldsymbol{z}) = \overline{d_0(\boldsymbol{z})} v(u, \boldsymbol{p}, \boldsymbol{z}) \\ \overline{d_0(\boldsymbol{z})} = (1 + \boldsymbol{\rho}' \boldsymbol{z}) \end{gathered} \tag{3.8}$$

where the vector $\boldsymbol{\rho}$ represents parameters that adjust the price index to include demographic data. Later, Poi (2002) defines an indirect utility function, v, as:

$$v(u, \boldsymbol{p}, \boldsymbol{z}) = \frac{\prod_{i=1}^{G} p_i^{\beta i} \left(\prod_{i=1}^{G} p_i^{\boldsymbol{\eta_i}' \boldsymbol{z}} - 1 \right)}{\frac{1}{u} - \sum_{i=1}^{G} \lambda_i \, ln p_i} \tag{3.9}$$

where the vector $\boldsymbol{\eta_i}$ represents the parameter estimates that measure the effects of demographic variables on expenditure elasticity for good i. As a result, the expenditure share equations of AIDS become:

$$w_i = \alpha_i + \sum_j \gamma_{ij} ln p_j + (\beta_i + \boldsymbol{\eta_i'} \boldsymbol{z}) ln \left(\frac{m}{\overline{d_0}(\boldsymbol{z}) a(\boldsymbol{p})} \right) \tag{3.10}$$

Equation (3.10) extends Equation (3.6) by incorporating the matrix of demographic effects, $\boldsymbol{z}$, into the by rescaling the relationship between expenditure shares and deflated expenditure as $(\beta_i + \boldsymbol{\eta_i'} \boldsymbol{z})$ and the deflated expenditure as $\frac{m}{\overline{d_0}(\boldsymbol{z}) a(\boldsymbol{p})}$. A positive $(\beta_i + \boldsymbol{\eta_i'} \boldsymbol{z})$ implies that the good i is a normal good given an associated set of values for demographic variables and the values of parameters β_i and η_i. Moreover, based on the vector $\boldsymbol{\rho}$, if $\overline{d_0(\boldsymbol{z})} < 0$, the value of deflated expenditure is larger than $\frac{m}{a(p)}$.

3.3.2.4 Quadratic Extensions to AIDS

The Engel curves for the AIDS model are of the linear Working–Leser form (Working, 1943; Leser, 1963):

$$w_i \;= \omega_i \; + \psi_i ln m \tag{3.11}$$

where w_i is the expenditure share of good i and lnm is the logarithm of total expenditures. Gorman (1981) found that the maximum possible rank of Engel curves

is three under exact aggregability; in other words, all budget shares can be described by a linear combination of three linearly independent functions of income. Then, Lewbel (1991) has illustrated that the rank concept is applicable to any demand system and has many implications for separability, functional form, and aggregation across products and agents. Moreover, they have empirically found significant nonlinearities in budget shares. Furthermore, Banks et al. (1997) have shown that the Engel curves of many commodities display nonlinear behavior via nonparametric kernel and quadratic polynomial regressions. Thus, a linear Working–Leser form must be extended with an additional nonlinear expenditure term.

$$w_i = A_i(p) + B_i(p) ln\left(\frac{m}{a(p)}\right) + C_i(p) f\left(\frac{m}{a(p)}\right) \tag{3.12}$$

where A_i, B_i, amd C_i are differentiable functions of prices and f is a nonlinear differentiable function of deflated expenditure. If the budget equation is in the form of $w_i = A_i(p)$, homothetic preferences are present so that expenditure shares are unaffected by income level (rank=1). The Working–Leser form that is suitable for AIDS is characterizes the structure if the function is $w_i = A_i(p) + B_i(p) ln\left(\frac{m}{a(p)}\right)$ (rank 2). Based on the theoretical and empirical studies mentioned above, the expenditure-share equation is in its best form in Equation (3.12) (rank 3). Besides, Banks et al. (1997) have shown that the budget share systems with rank 3 have the indirect utility function:

$$lnV(\boldsymbol{p}, m) = \left[\left(\frac{lnm - lna(\boldsymbol{p})}{b(\boldsymbol{p})}\right)^{-1} + \lambda(\boldsymbol{p})\right]^{-1} \tag{3.13}$$

where $\frac{lnm - lna(p)}{b(p)}$ is the indirect utility function obtained by Equation (3.3). Equation (3.13) can be rewritten as $lnm = lna(p) + b(p)\frac{1}{(lnV)^{-1} - \lambda(p)}$. Substituting $m = e(u, \boldsymbol{p})$ and applying duality, $V(\boldsymbol{p}, m) = V\big(\boldsymbol{p}, e(\boldsymbol{p}, u)\big) = u$, the expenditure function, $lne(\boldsymbol{p}, u) = \frac{b(\boldsymbol{p})}{u^{-1} - \lambda(\boldsymbol{p})} + lna(\boldsymbol{p})$ is obtained. Finally, applying Sheppard's lemma and incorporating demographic scaling components, the QUAIDS budget share equation is obtained as follows:

$$w_i = \alpha_i + \sum_j \gamma_{ij} lnp_j + (\beta_i + \eta_i' z) ln\left(\frac{m}{\overline{d_0}(\boldsymbol{z})a(p)}\right) + \frac{\lambda_i}{b(p)\, c(p,z)}\left[ln\left(\frac{m}{\overline{d_0}(\boldsymbol{z})a(p)}\right)\right]^2 \tag{3.14}$$

where $c(p, \boldsymbol{z}) = \prod_i p_i^{\boldsymbol{\eta_i' z}}$. The Equation (3.14) is consistent with rational consumer preferences that require adding up, homogeneity, and Slutsky symmetry. Hence, the following conditions must be satisfied:

$$\sum_i \alpha_i = \sum_i w_i\,, \qquad \sum_i \beta_i = 0, \qquad \sum_i \gamma_{ij} = 0, \qquad \sum_i \lambda_i = 0, \qquad \sum_i \eta_{Di} = 0, \qquad and\ \gamma_{ij} = \gamma_{ji} \tag{3.15}$$

3.3.2.5 Handling Censored Dependent Variables

In the applied analysis of demand systems, one of the most challenging and common problems arises when the observations have zero expenditures on certain commodity groups. This implies censored dependent variables in expenditure-share equations. To overcome this problem, Heien & Wessells (1990) suggest the use of inverse Mills ratio (R) as an additional explanatory variable for each equation in the AIDS. This ratio is calculated for each good and each observation as

$$R_{ih} = \frac{\phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)}{\Phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)}, if\ m_{ih} > 0$$
$$R_{ih} = \frac{\phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)}{1 - \Phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)}, if\ m_{ih} = 0 \tag{3.16}$$

where $\phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)$ is the normal probability density function that is obtained from probit estimation determining the probability that a given observation will consume the good, which is a function of demographic characteristics while $\Phi_{ih}(\boldsymbol{p_h}, \boldsymbol{z_h}, m_h)$ is the associated normal cumulative density function. However, Shonkwiler & Yen (1999) claim that it is empirically better insert densities into the equations without the need to define inverse Mills ratio. They suggest the budget equations of the form:

$$w_i^* = \Phi_i(\boldsymbol{p}, \boldsymbol{z}, m) w_i + \delta_i \phi_i(\boldsymbol{p}, \boldsymbol{z}, m) \tag{3.17}$$

where δ_i is a nonzero parameter adjusting the consumption probabilities and $w_i^* > 0$ no matter the value of w_i. If $w_i > 0$ for all observations, the normal cumulative density function and associated probability density function satisfy $\Phi_i(\boldsymbol{p}, \boldsymbol{z}, m) = 1$ and $\phi_i(\boldsymbol{p}, \boldsymbol{z}, m) = 0$, preserving the actual observations. On the other hand, for any observation where $w_i = 0$ or $w_i = 1$, they adjust w_i^*, with $0 < \Phi_i(\boldsymbol{p}, \boldsymbol{z}, m) < 1$ and $0 < \phi_i(\boldsymbol{p}, \boldsymbol{z}, m) < 1$.

3.3.2.6 Parameter Estimation

Substituting the Equation (3.14) into (3.17), the following expenditures share equation for each good i constituting censored QUAIDS with demographic scaling are obtained:

$$\begin{aligned} w_i^* = \Phi_i(\boldsymbol{p}, \boldsymbol{z}, m) \Bigg(& \alpha_i + \sum_j \gamma_{ij} ln p_j + (\beta_i + \eta_i' z) ln \left(\frac{m}{\overline{d_0}(\boldsymbol{z}) a(p)} \right) \\ & + \frac{\lambda_i}{b(\boldsymbol{p})\, c(\boldsymbol{p}, \boldsymbol{z})} \left[ln \left(\frac{m}{\overline{d_0}(\boldsymbol{z})(\boldsymbol{p})} \right) \right]^2 \Bigg) + \delta_i \phi_i(\boldsymbol{p}, \boldsymbol{z}, m) \\ & + u_i \end{aligned} \tag{3.18}$$

Using Equation (3.18) and imposing the constraints in (3.15) as well as $\sum_i \delta_i = 0$, a nonlinear seemingly unrelated regression (NLSUR) is estimated for stages 3-5. For each stage, the processes are handled by dropping one of the expenditure equations due to the reason explained above.

3.3.2.7 Calculating Elasticities

The income, Marshallian, and Hicksian price elasticities of demand are defined as

$$\begin{aligned} \mu_i &= \frac{\partial x_i(\boldsymbol{p}, \boldsymbol{z}, m)}{\partial m} \frac{m}{x_i(\boldsymbol{p}, \boldsymbol{z}, m)} \\ \epsilon_{ij}^U &= \frac{\partial x_i(\boldsymbol{p}, \boldsymbol{z}, m)}{\partial p_j} \frac{p_j}{x_i(\boldsymbol{p}, \boldsymbol{z}, m)} \\ \epsilon_{ij}^C &= \epsilon_{ij}^U + \mu_i w_i^* \end{aligned} \tag{3.19}$$

where $x_i(\boldsymbol{p}, \boldsymbol{z}, m) = \frac{m}{p_i} w_i^*(\boldsymbol{p}, \boldsymbol{z}, m)$ is uncompensated demand function of good i. Thus, the elasticities can be rewritten as a function of predicted values for w_i^* , or $\widehat{w_i^*}$

$$\mu_i = \Phi_i \frac{1}{\widehat{w_i^*}} \frac{\partial w_i}{\partial m}$$

$$\epsilon_{ij}^U = \Phi_i \frac{1}{\widehat{w_i^*}} \frac{\partial w_i}{\partial p_j} \tag{3.20}$$

$$\epsilon_{ij}^C = \epsilon_{ij}^U + \mu_i \widehat{w_j^*}$$

The income elasticity of demand, μ_i, refers to the percentage change in the quantity demanded of the good i in response to 1% change in the household income. Similarly, the uncompensated price elasticity, ϵ_{ij}^U, refers to the percentage change in the quantity demanded of the good i in response to 1% change in the price of the good j. Finally, the compensated price elasticity, ϵ_{ij}^C, is the pure price elasticity that is adjusted by eliminating the income effect, $-\mu_i \widehat{w_j^*}$. If $i = j$, they are called own-price elasticity; otherwise, they are cross-price elasticities.

3.3.3 Application

In the first stage, Equation (3.1) is estimated with OLS with factor weights and predicted values, $\overline{ln(E_h)}$, are obtained. Similarly, in the second stage, $\overline{ln(F_h)}$ is obtained from Equation (3.2).

In stages 3-5, the following probit functions are estimated in order to include a correction for sample selection bias

$$B_{i,h_3} = \sum_{k=1}^{40} \omega_{k_3} D_{hk} + \zeta_{i,h_4}, if\ i \in N;\ h = 1, \dots H$$

$$B_{i,h_4} = \sum_{k=1}^{40} \omega_{k_4} D_{hk} + \zeta_{i,h_4}, if\ i \in M;\ h = 1, \dots H \tag{3.21}$$

$$B_{i,h_5} = \sum_{k=1}^{40} \omega_{k_5} D_{hk} + \zeta_{i,h_5}, if\ i \in S;\ h = 1, \dots H$$

where B_{i,h_3}, B_{i,h_4}, and B_{i,h_5} are binary variables, which equal to 1 if the consumer has a positive expenditure of good i in the set N, M, and S, respectively, and 0, otherwise, and are defined as functions of 14 demographic and socioeconomic characteristics and 26 regional dummies. The 14 demographic and socioeconomic characteristics include household size, life quality, ratio of household income to required basic income, expenditure on restaurants, tobacco, and alcohol, household wealth, levels of income required for a standard life and level of income required for a good life, and the numbers of bread, cigarette packs, movie tickets, lottery tickets, times dining out for a given period.

Once all the necessary variables are acquired, the 3rd stage system of equations dropping the subscript h, is constructed for $i = 5$ main food groups as follows:

$$\begin{aligned} w_{i_3} = \Phi_{i_3}\Bigg(& \alpha_{i_3} + \sum_{j=1}^{5} \gamma_{i j_3} ln p_{j_3} \\ & + \left(\beta_{i_3} + \boldsymbol{\eta}'_{\boldsymbol{i_3}} \boldsymbol{z}\right)\left[\widehat{ln(F)} - ln\left(\widehat{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_3})\right] \\ & + \frac{\lambda_{i_3}}{b(\boldsymbol{p_3}) c(\boldsymbol{p_3}, \boldsymbol{z})}\left[\widehat{ln(F)} - ln\left(\widehat{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_3})\right]^2 \Bigg) \\ & + \delta_{i_3} \phi_{i_3} + u_{i_3} \end{aligned} \tag{3.22}$$

However, the fifth equation in the system is dropped to avoid singularity in the covariance matrix due to the issues given in Equation (3.15). Once the parameters are estimated, predicted total logarithmic meat expenditures are obtained by:

$$\widehat{ln(M)} = \widehat{w_{1_3}} ln(F) \tag{3.23}$$

The 4th and 5th stage analogues of Equation (3.22) are as follows:

$$w_{i_4} = \Phi_{i_4}\Bigg(\alpha_{i_4} + \sum_{j=1}^{3}\gamma_{ij_4} lnp_{j_4} + \left(\beta_{i_4} + \boldsymbol{\eta}'_{\boldsymbol{i_4}}\boldsymbol{z}\right)\left[\widehat{ln(M)} - ln\left(\overline{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_4})\right] + \frac{\lambda_{i_4}}{b(\boldsymbol{p_4})c(\boldsymbol{p_4}, \boldsymbol{z})}\left[\widehat{ln(M)} - ln\left(\overline{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_4})\right]^2\Bigg) + \delta_{i_4}\phi_{i_4} + u_{i_4} \tag{3.24}$$

$$w_{i_5} = \Phi_{i_5}\Bigg(\alpha_{i_5} + \sum_{j=1}^{3}\gamma_{ij_5} lnp_{j_5} + \left(\beta_{i_5} + \boldsymbol{\eta}'_{\boldsymbol{i_5}}\boldsymbol{z}\right)\left[\widehat{ln(S)} - ln\left(\overline{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_5})\right] + \frac{\lambda_{i_5}}{b(\boldsymbol{p_5})c(\boldsymbol{p_5}, \boldsymbol{z})}\left[\widehat{ln(S)} - ln\left(\overline{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_5})\right]^2\Bigg) + \delta_{i_5}\phi_{i_5} + u_{i_5} \tag{3.25}$$

where $\widehat{ln(S)} = \widehat{w_{1_4}} ln(M)$. Lastly, the elasticities are computed by Equation (3.20) for each good in each stage.

The multi-stage budgeting approach in this study, characterized by the equations (3.1), (3.2), (3.22), (3.24), and (3.25), presents an alternative procedure. To begin with, it addresses the importance of expenditure-saving decisions in the analysis to account for endogeneity. Given the presence of households with both negative and positive savings, the initial budgeting choice for a household involves determining the expenditure amount based on their income levels and other socioeconomic characteristics at a specific point in a cross-sectional data set. If this study, like many prior studies, had analyzed how households distribute their income, overall expenditures, or food expenditures among specific sub-expenditure categories as their primary decision, the error term in Equation (3.1), u_{h_1}, would influence the parameters estimated in subsequent stages, resulting in biased estimators.

Next, this study uniquely replaces the demographic translation with the demographic scaling technique without neglecting the need for a correction for censored dependent variables. This approach provides two advantages. First, unlike the parameters

estimated under demographic translation that directly determine expenditure shares but indirectly affect elasticities, the parameters under demographic scaling directly determine the elasticities computed. Secondly, various households, despite having identical overall expenditures, will demonstrate distinct spending patterns influenced by their socioeconomic characteristics. General equivalence scales depicted in equations (3.7) and (3.8) assess households of differing characteristics and evaluate the relative expenses associated with achieving an equivalent level of utility. Thus, by rescaling deflated expenditures for each observation in each stage, demographic scaling technique allows to control for the variations among households.

3.4 Data Set

3.4.1 Defining Key Variables

The HBS2003 data set includes the prices and expenditures for $N = 1554$ food commodities and only expenditure shares for other commodities for each household. After eliminating outliers and inconsistent observations for each stage, the analysis is conducted with $H = 25250$ observations. First, this study defines each household's expenditure shares of all food commodities, w_{hi}, from their total food expenditures. By using these expenditure shares, the weighted average of prices is computed to obtain an overall food price level, P_h, for each household.

$$P_h = \sum_{i=1}^{N} w_{hi} p_{hi}\,, \quad i = 1, \dots, N; h = 1, \dots, H \tag{3.26}$$

where p_{hi} is commodity prices each household faces. The shares are aggregated for each household and determined food, F_a, animal meat, M_b, and seafood, S_c, groups.

$$\begin{aligned} w_{h_{f_a}} &= \sum_{i=1} w_{hi}\,, if\ i \in F_a;\ h = 1, \dots H;\ a = 1, \dots, 5 \\ w_{h_{m_b}} &= \sum_{i=1} w_{hi}\,, if\ i \in M_b;\ h = 1, \dots H;\ b = 1, \dots, 3 \\ w_{h_{s_c}} &= \sum_{i=1} w_{hi}\,, if\ i \in S_c;\ h = 1, \dots H;\ c = 1, \dots, 3 \end{aligned} \tag{3.27}$$

and the price levels for each group are obtained by the same idea:

$$p_{h_{f_a}} = \sum_{i=1} w_{hi}\, p_{hi}, if\ i \in F_a;\ h = 1, \dots H;\ a = 1, \dots, 5$$

$$p_{h_{m_b}} = \sum_{i=1} w_{hi}\, p_{hi}, if\ i \in M_b;\ h = 1, \dots H;\ b = 1, \dots, 3 \qquad (3.28)$$

$$p_{h_{s_c}} = \sum_{i=1} w_{hi}\, p_{hi}, if\ i \in S_c;\ h = 1, \dots H;\ c = 1, \dots, 3$$

These prices are first obtained for all households that make consumption in the associated food group, then, the missing prices are determined by the regional average prices by NUTS2. The associated zero expenditure shares are handled by the two-step procedure suggested by Shonkwiler and Yen (1999). The monthly income, total expenditures, total food expenditures, and total expenditures for each group are either readily available in the data set or easily obtained by simple aggregation.

Moreover, four demographic and socioeconomic variables are defined in addition to income, expenditures, expenditure shares, and prices. First, household size (D_1) is an essential demographic variable in the analysis; however, the equivalent household size (OECD) is considered instead of the number of people. It is calculated by assigning values of 1 to the first adult residing in the household, 0.5 to individuals aged fourteen years and older, and 0.3 to those younger than fourteen. Secondly, it is considered that life quality can be reflected by the rental value of the house lived (D_2). This variable is constructed by the monthly rent payments of tenants and one-211th of the present value of the dwelling for owner-occupiers. However, these values themselves may not reflect the true value and quality of the house lived, depending on the other variables. Thus, its predicted values are obtained by OLS, with explanatory variables including the number of rooms, the age of the building, years of living in the same house, the equivalent household size (D_1), the ability of the household to meet its basic needs (D_3), and the dummy variable taking the value of zero if the household is a tenant. Third, the ability of the household to meet its basic needs (D_3) is obtained by dividing their income by the income level required for a minimum living level, which is estimated and recorded for each household in the data set. Finally, some portion of the nonfood expenditures, which are, in fact, directly related to the food expenditures, is obtained for each household. The total value of restaurant, tobacco, and alcohol (RTA)

expenditures is considered another socioeconomic variable (D_4) as these consumption habits can be closely associated with the household food demand. It is expected that any consumption of restaurant services reduces the food expenditures from grocery stores. Moreover, various alcoholic beverages are frequently consumed along with certain food types in Turkish cuisine. Finally, tobacco is an addictive substance for individuals that might indirectly affect food consumption behavior.

Furthermore, in order to estimate Equation 3.21, some variables that can influence the probability of consuming from any food group are included in the analysis. In addition to four demographic and socioeconomic characteristics mentioned above and 26 regional dummies, the consumptions of daily number of breads and weekly packs of cigarettes, monthly restaurant and cinema visits and lottery frequencies, numbers of students and insured people in the household, total value of property owned by household members, and the required income levels for normal and good lives are considered independent variables.

3.4.2 Descriptive Statistics

In accordance with the study's methodological objectives, the most important prior knowledge about the variables is the zero observations and the distributions of expenditure shares, which are, by definition, between 0 and 1. Table 3.5 illustrates the number of households who reported that they did not make any consumption from the given set of products during the month that they joined the survey. The relatively low number of zeros may not pose a problem; however, as the product groups get more disaggregated, their appearance increases, resulting in highly censored dependent variables in the expenditure-share equations of the demand system. Especially for seafood consumption and its subgroups, the share of zero consumption is at least 66% since the survey might be conducted during seasonal closure of fisheries. For several reasons, either eliminating those observations or accepting them as given leads to sample selection bias. First, simple elimination results in a loss of around 95% of observations, leading to an analysis with a very small sample of seafood consumers. However, there might be the ones that may dislike seafood. Secondly, accepting them as given is also not reasonable due to the limitations of the data set arising from the survey process. Not all the observations were interviewed in the same month of 2003. Given that seafood consumption is expected to have a seasonal pattern, it is possible

for a household in the sample to be surveyed in the off-season. Next, there are geographic differences in observations, and another sampling for each region might change the portion of zeros.

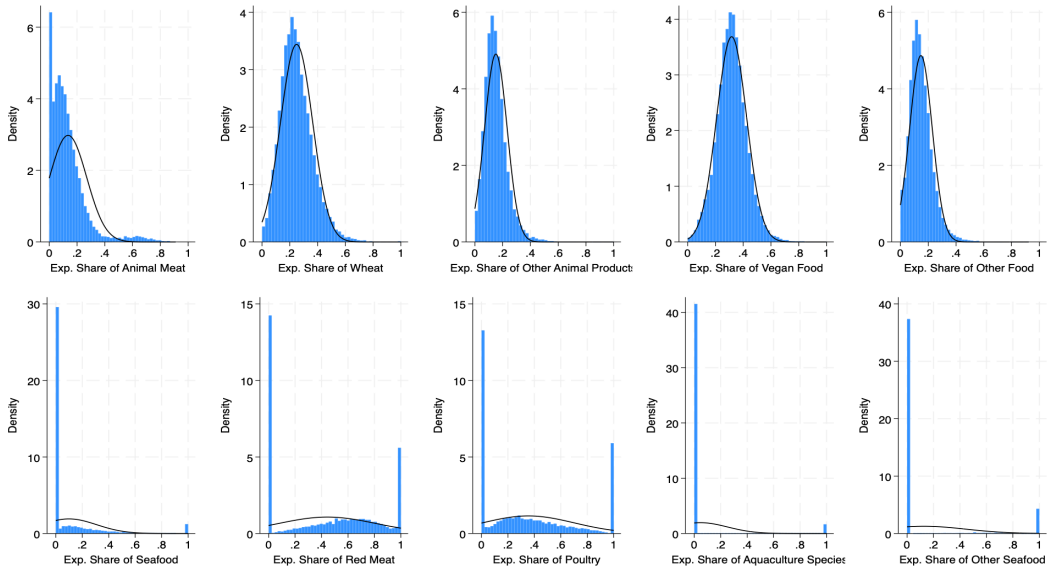
Table 3.5 Summary Statistics for Expenditure Shares

Exp. Share	Mean	Std. D.	Skew.	Kurt.	Min.	Max.	Zeros
Animal Meat	0.136	0.134	2.253	9.620	0	0.910	2584
Wheat	0.249	0.116	0.797	4.428	0	1	49
Other Animal Products	0.151	0.081	1.377	7.671	0	1	166
Vegan Food	0.317	0.108	0.286	3.863	0	1	26
Other Food	0.147	0.082	1.213	6.738	0	0.924	308
Seafood	0.099	0.209	2.827	11.232	0	1	16651
Red Meat	0.444	0.372	0.065	1.543	0	1	8174
Poultry	0.355	0.347	0.675	2.172	0	1	7352
Anchovy	0.166	0.358	1.801	4.368	0	1	20310
Aquaculture Species	0.047	0.203	4.244	19.433	0	1	23836
Other Seafood	0.127	0.316	2.222	6.149	0	1	21439
N	25250						

Source: TurkStat Household Budget Survey 2003

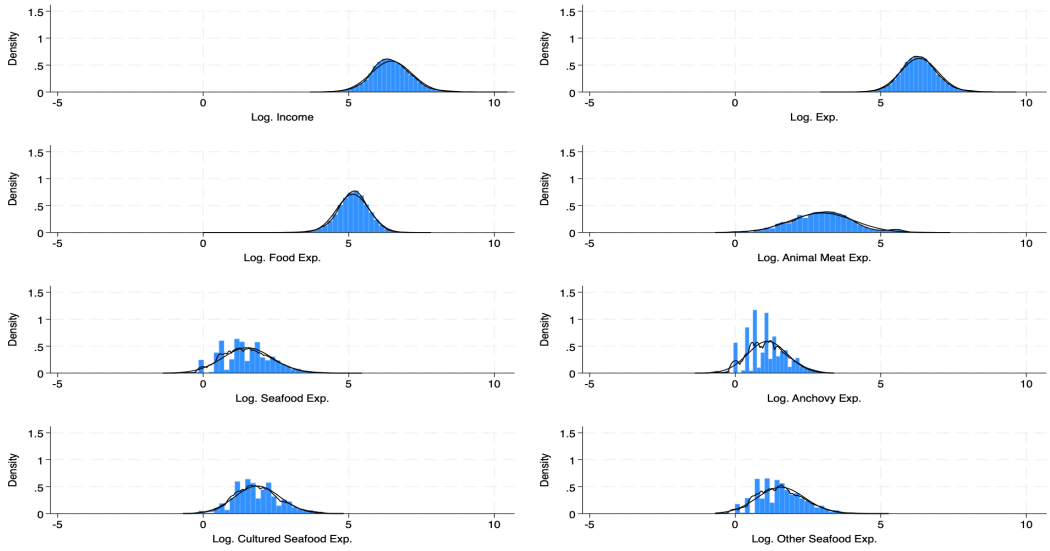
In addition to the zero observations, key descriptive statistics may also help to understand the initial requirements for the analysis process. First, a simple summation of mean expenditures shows that the adding-up condition may not hold in censored demand systems if some households did not consume a single product from a given subgroup. All households consumed food; thus, initial shares of food groups sum to 1. However, 10.2% of households were reported as having nonconsumption of animal meat; hence, the shares in the next stage sum to 0.898. In the final stage, the further disaggregated shares of different seafood types sum to 0.34. Secondly, it can be observed that the food groups that are the primary interest of this study have the lowest shares compared to others (0.136 for animal meat and 0.099 for seafood). Moreover, red meat, poultry, and anchovy shares show the largest variations, demonstrating that their consumption shares are not as concentrated as others in certain segments.

Figure 3.2 Distributions of Expenditure Share Densities



Moreover, the skewness values are all positive for the shares, indicating longer tails to the right (Figure 3.2). High kurtosis values for animal meat, seafood, and their subgroups indicate heavier tails or greater extreme values of zeros or ones. Figure 3.2 also illustrates the normal distributions of expenditure shares, which are the dependent variables in expenditure-share equations and are frequently truncated at zero or one, leading to potential inconsistencies in the econometric models (Amemiya, 1974). As a result, all these issues highlight the necessity of consideration for censored dependent variables in the sequential analysis.

Figure 3.3 Distributions of Logarithmic Expenditure Densities



Another essential aspect of the present study is that the demand systems are constructed by the logarithms of incomes and expenditures. However, if any

expenditure share or aggregate expenditure is zero, taking their logarithms leads to missing observations, although their distributions seem normal in that case (Figure 3.3). Thus, in addition to being a cure for endogeneity, using their predicted values instead of their own values saves all the observations in the data set.

Table 3.6 illustrates key descriptive statistics for the price levels of the determined groups. The highest average price is paid for red meat, which has the highest variability, while the lowest is paid for anchovy. The positive skewness and large kurtosis values show that high individual price levels exist and are rare, and prices are more concentrated around the mean.

Table 3.6 Summary Statistics for Price Levels of Food Groups

	Mean	Std. D.	Skew.	Kurt.	Min.	Max.
Animal Meat	1.095	1.140	2.522	11.192	0.002	8.966
Wheat	0.329	0.323	7.103	85.766	0.001	6.372
Other Animal Products	0.330	0.283	2.032	10.132	0.001	2.937
Vegan Food	0.496	0.273	2.122	13.288	0.003	3.495
Other Food	0.521	0.463	3.344	23.280	0.001	6.381
Seafood	0.115	0.138	9.654	166.222	0.001	4.468
Red Meat	1.181	1.023	2.986	14.783	0.001	8.954
Poultry	0.206	0.168	5.577	86.966	0.002	5.617
Anchovy	0.037	0.019	6.814	110.908	0.001	0.664
Aquaculture Species	0.237	0.130	4.692	71.425	0.001	3.449
Other Seafood	0.115	0.083	13.070	446.065	0.002	4.468

Source: TurkStat Household Budget Survey 2003

Finally, Table 3.7 demonstrates summary statistics for the demographic variables. Another essential aspect of the study is that it assumes quadratic Engel curves (relationship between quantity and expenditure) in the analysis to rely on QUAIDS. However, this is more than an assumption, as nonlinearities are observed in the relationship between income or group expenditures and deflated subgroup expenditures. First, all deflated expenditures are computed by dividing group expenditures by group prices in each stage. Then, linear and quadratic relationships are visualized.

Table 3.7 Summary Statistics for Demographic Variables

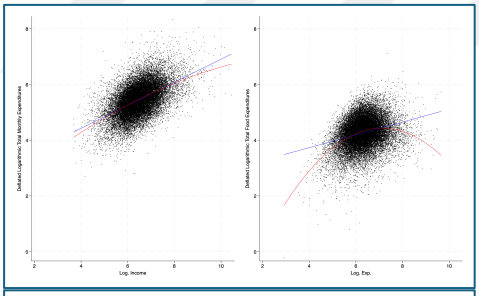
	Mean	Std. D.	Skew.	Kurt.	Min.	Max.
Equivalent Household Size (OECD)	2.363	0.850	1.573	8.198	1.000	10.200
Predicted Rental Value of the House Lived	1.158	0.372	1.005	14.984	-1.201	6.378
Ability to Meet Basic Needs	1.185	0.962	5.499	68.000	0.101	22.938
Total Rest., Alc., and Tob. Exp. (1000 TL)	0.044	0.051	2.498	17.207	0.000	0.970

Source: TurkStat Household Budget Survey 2003

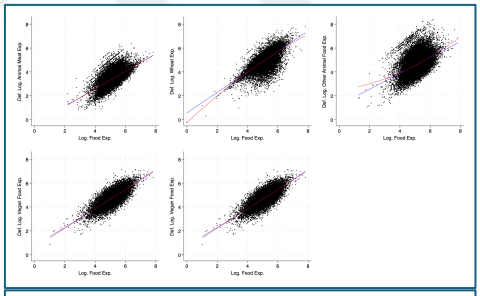
In the first stage, the linear and quadratic relationships between deflated logarithmic monthly total expenditures and logarithmic income levels are obtained. Then, the same is done for food expenditures and total expenditures (Figure 3.4-a). At least a small distinction between linear and quadratic fits is observed in Stage 1 and Stage 2. The relationships in Stage 3, Stage 4, and Stage 5 are visualized in Figure 3.4-b, -c, and -d., respectively. Since at least one distinctive quadratic curve is observed in each stage, this study insists on the QUAIDS application in the stages where there are more than two options.

Figure 3.4 Linear and Quadratic Relationships

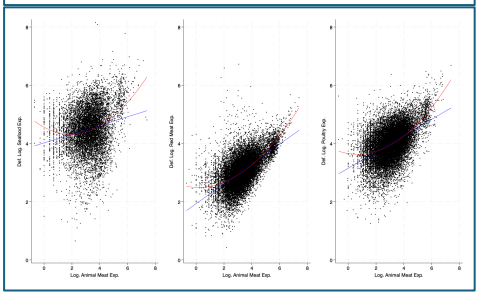
a



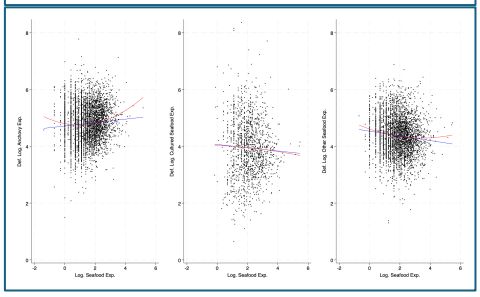
c



b



d



Stage1: Total expenditures and income (a)
Stage2: Food expenditures and total expenditures (a)
Stage3: Main food group expenditures and food expenditures (b)
Stage4: Animal meat group expenditures and total animal meat expenditures (c)
Stage5: Seafood group expenditures and total seafood expenditures (d)

3.5 Results

The first stage regression is estimated with robust standard errors and analytical factor weights. It is considered as logarithmic expenditure is a function of logarithmic income and its square, logarithmic food price level as a proxy for overall price level each household faces, and four demographic variables (Table 3.8). The second stage regression is also estimated with the same structure. The logarithmic total expenditure, (lnE_h), is replaced by its predicted values, $\widehat{ln(E_h)}$, which are obtained in the previous stage.

Table 3.8 Parameter and Elasticity Estimates of the First Stage Regression

$\boldsymbol{lnE_h}$	**Coeff. Est.**
Intercept	2.516***
	(0.195)
$ln(I_h)$	0.318***
	(0.060)
$ln(I_h)^2$	0.020***
	(0.005)
$ln(P_h)$	0.353***
	(0.008)
D_{h1}	0.136***
	(0.006)
D_{h2}	0.311***
	(0.017)
D_{h3}	-0.152***
	(0.007)
D_{h4}	1.858***
	(0.061)
Number of observations	25250
R^2	0.681
$\mu_{I,1}$	0.368
$\mu_{UP,1}$	-0.952
$\mu_{CP,1}$	-1.593

Robust standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

All coefficients except intercept are found to be significant at 5% significance level. Logarithmic food expenditures are increasing in a decreasing rate with the fitted total expenditures with average expenditure elasticity of $\mu_{I,2} = 1.413$. They are also increasing with food price level with unit uncompensated and compensated price elasticity of $\mu_{UP,2} = -0.939$ and $\mu_{CP,2} = -0.798$ (Table 3.9). Moreover, households'

expenditure preferences move toward to food with household size and ability to meet basic needs, while households with better houses and greater habits towards RTA consumptions. These results are more intuitive compared to the first stage.

Table 3.9 Parameter and Elasticity Estimates of the Second Stage Regression

$\boldsymbol{lnF_h}$	**Coeff. Est.**
Intercept	-0.698*
	(0.364)
$\widehat{ln(E_h)}$	1.273***
	(0.113)
$\widehat{ln(E_h)}^2$	-0.066***
	(0.009)
$ln(P_h)$	0.363***
	(0.012)
D_{h1}	0.167***
	(0.007)
D_{h2}	-0.243***
	(0.020)
D_{h3}	0.069***
	(0.006)
D_{h4}	-1.048***
	(0.074)
Number of observations	25250
R^2	0.451
$\mu_{I,2}$	1.413
$\mu_{UP,2}$	-0.939
$\mu_{CP,2}$	-0.798

Robust standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

The QUAIDS estimated in the next stages are conducted by considering demographic scaling based on the four variables and censored dependent variables which represent zero expenditure shares in the demand systems (Equation (3.18)). To reduce a possible sample selection bias, for each food group, the probability of consuming from it is estimated by a linear probit model, as a function of a set of demographic and regional variables. Then, the obtained standard normal cumulative and associated probability distribution functions for each group are incorporated into the expenditure share equations of the demand systems (Equation (3.17)).

Table 3.10 Parameter Estimates of the Third Stage QUAIDS

	α_{i_3}	β_{i_3}	λ_{i_3}	δ_{i_3}	
Meat	-0.2321***	0.3713***	-0.1094***	0.0308***	
	(0.0068)	(0.0027)	(0.0039)	(0.0032)	
Wheat	0.3982***	-0.0731***	0.0119***	0.2399***	
	(0.0028)	(0.0029)	(0.0015)	(0.0296)	
Dairy	0.2221***	-0.0630***	0.0212***	0.2588***	
	(0.0016)	(0.0025)	(0.0013)	(0.0191)	
Vegan	0.4030***	-0.1339***	0.0448***	0.0518	
	(0.0030)	(0.0029)	(0.002)	(0.0514)	
Other	0.2088***	-0.1013***	0.0314***	-0.5812***	
	(0.0019)	(0.0028)	(0.0015)	(0.0589)	
γ_{ij_3}	Meat	Wheat	Dairy	Vegan	Other
Meat	-0.0601***	0.0131***	0.0095***	0.0243***	0.0132***
	(0.0016)	(0.0008)	(0.0007)	(0.0009)	(0.0008)
Wheat	0.0131***	0.0901***	-0.021***	-0.0598***	-0.0224***
	(0.0008)	(0.0006)	(0.0003)	(0.0005)	(0.0004)
Dairy	0.0095***	-0.021***	0.049***	-0.0269***	-0.0106***
	(0.0007)	(0.0003)	(0.0004)	(0.0004)	(0.0003)
Vegan	0.0243***	-0.0598***	-0.0269***	0.0934***	-0.031***
	(0.0009)	(0.0005)	(0.0004)	(0.0008)	(0.0004)
Other	0.0132***	-0.0224***	-0.0106***	-0.031***	0.0507***
	(0.0008)	(0.0004)	(0.0003)	(0.0004)	(0.0005)
$\eta_{i_3 D_d}$	z_{D_1}	z_{D_2}	z_{D_3}	z_{D_4}	
Meat	0.0019***	0.0028**	-0.0010***	-0.0134***	
	(0.0004)	(0.0012)	(0.0003)	(0.0036)	
Wheat	0.0002	-0.0166***	0.0028***	0.005	
	(0.0004)	(0.0014)	(0.0004)	(0.0045)	
Dairy	0.0021***	0.0007	-0.0005	-0.035***	
	(0.0004)	(0.0011)	(0.0003)	(0.0034)	
Vegan	-0.0039***	-0.0001	0.0007**	-0.0033	
	(0.0004)	(0.0012)	(0.0004)	(0.0039)	
Other	-0.0002	0.0132***	-0.0021***	0.0467***	
	(0.0004)	(0.0012)	(0.0003)	(0.0037)	
ρ_{3d}	1.3554***	-0.42***	0.0432***	-2.4904***	
	(0.0587)	(0.038)	(0.0123)	(0.2254)	

Robust standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

In the third stage, the system presented in Equation (3.22) is estimated to obtain the 69 parameters for $i = 5$ goods and $d = 4$ demographic variables (Table 3.10). The total food expenditure, lnF_h, is replaced by its predicted values, $\widehat{ln(F)}$, acquired in the second stage. The constant terms in expenditure share equations, α_{i_3}'s would exactly equal to the expenditure shares, w_{i_3}'s, if all prices were normalized to one and all expenditures were reduced to $\alpha_{0_3} = min\left[\widehat{ln(F_h)}\right] = 3.44$, which is the constant term

of the Equation (3.4). Thus, they sum to the same value which w_{i_3} does, which is 1 in the third stage. Additionally, they have a role in the determination of the price index $lna(\boldsymbol{p_3})$, together with γ_{ij_3}'s. Thus, α_{i_3}, γ_{ij_3}, and ρ_{3d} (Equation (3.8)) are the parameters that jointly modifies deflated food expenditure, $\widehat{ln(F)} - ln\left(\overline{d_0(\boldsymbol{z})}\right) - lna(\boldsymbol{p_3})$.

Next, γ_{ij_3} estimates measure the effects of the logarithmic prices, lnp_{j_3}, on the level of expenditure shares, w_{i_3}. Table 3.10 shows that expenditure share of meat is reduced by its own price, while increasing with other prices. Since $\gamma_{ij_3} = \gamma_{ji_3}$ by the conditions in Equation (3.15), these relationships are symmetrical as observed in the table.

All components in the term $\left(\beta_{i_3} + \boldsymbol{\eta}'_{\boldsymbol{i_3}}\boldsymbol{z}\right)$ of the Equation (3.22) and λ_{i_3} are the parameters that jointly measure the sensitivity of expenditure shares to the levels of deflated expenditure. If the deflated expenditure is positive, positive and larger values of these parameters indicate an increase in the expenditure share. However, the effect of the parameters in the vector $\boldsymbol{\eta}'_{\boldsymbol{i_3}}$ depends on the sign of its associated demographic variable. Its effect will be like β_{i_3}'s one if the demographic variable is positive. Besides, since it is associated with the quadratic deflated expenditure, λ_{i_3} has a greater impact on expenditure share of good i. For meat, the estimates $\beta_{1_3} = 0.3713$, and $\lambda_{1_3} = -0.1094$ are both significant, indicating concavity among shares and deflated expenditure. Table 3.10 also shows that the signs for other goods are in opposite direction.

Moreover, given that the term $\boldsymbol{\eta}'_{\boldsymbol{i_3}}\boldsymbol{z}$ is included in the elasticities, the parameter $\boldsymbol{\eta}'_{\boldsymbol{i_3}}$ also demonstrates the effect of demographic variables on them. If we differentiate the elasticities in Equation 3.20 with respect to z_{D_d}, the change of expenditure elasticities will have the same sign with the estimated parameter, $\eta_{i_3 D_d}$, while the change in the uncompensated own-price and cross-price elasticities will be in opposite direction.

Table 3.11 Elasticity Estimates of the Third Stage QUAIDS

		Meat	Wheat	Dairy	Vegan	Other
μ_{I_3}		1.840	0.754	0.927	0.871	0.895
ϵ_{UP_3}	Meat	-0.940	-0.042	-0.022	-0.049	-0.026
	Wheat	-0.014	-0.886	-0.007	-0.030	-0.007
	Dairy	-0.010	-0.016	-0.948	-0.019	-0.006
	Vegan	-0.022	-0.042	-0.016	-0.882	-0.018
	Other	-0.015	-0.015	-0.006	-0.020	-0.943
ϵ_{CP_3}	Meat	-0.687	0.415	0.256	0.533	0.245
	Wheat	0.090	-0.699	0.107	0.208	0.104
	Dairy	0.118	0.215	-0.808	0.274	0.130
	Vegan	0.098	0.174	0.115	-0.607	0.111
	Other	0.108	0.207	0.129	0.263	-0.811

Source: Own calculations

That is to say, if a good is normal and not Giffen, and it is a substitute to another good, positive and significant estimates of these parameters improve all elasticities. Table 3.10 shows that households with larger household size, better home quality, more unable to meet their basic needs, and less likely to visit restaurants or consume tobacco or alcohol have larger expenditure and price elasticities of meat demand. To put it differently, the households with these characteristics are more sensitive in meat consumption with the changes in meat prices and their total food expenditures.

Table 3.11 illustrates the third stage elasticities computed by the estimated parameters for a representative household with average expenditure shares, food expenditures, prices, demographics and probability densities. All goods are found to be normal with positive expenditure elasticities. Additionally, all food groups have food expenditure elasticities less than unity except meat, which is clearly more luxury than others. Uncompensated price elasticities show that all own-price elasticities are negative and less than one in absolute value, indicating that households have limited responses to price changes. All food groups seem slightly complements to each other including the food expenditure effect; however, compensated price elasticities show that they are substitutes.

Table 3.12 Parameter Estimates of the Fourth Stage QUAIDS

	α_{i_4}	β_{i_4}	λ_{i_4}	δ_{i_4}
Seafood	0.1323*** (0.0058)	0.3642*** (0.0352)	0.3309*** (0.0106)	0.1382*** (0.006)
Red Meat	0.4524*** (0.0056)	0.1217*** (0.039)	-0.5148*** (0.0123)	0.3368*** (0.0096)
Poultry	0.3134*** (0.0056)	-0.486*** (0.0409)	0.1839*** (0.0107)	-0.475*** (0.0101)
γ_{ij_4}	Seafood	Red Meat	Poultry	
Seafood	0.0393*** (0.0027)	-0.0539*** (0.0023)	0.0147*** (0.0025)	
Red Meat	-0.0539*** (0.0023)	0.2142*** (0.003)	-0.1602*** (0.0029)	
Poultry	0.0147*** (0.0025)	-0.1602*** (0.0029)	-0.1456*** (0.0038)	
$\eta_{i_4 D_d}$	z_{D_1}	z_{D_2}	z_{D_3}	z_{D_4}
Seafood	-0.0535*** (0.007)	-0.2243*** (0.0222)	0.0441*** (0.0065)	-0.2937*** (0.071)
Red Meat	-0.0036 (0.0075)	0.0754*** (0.0241)	-0.0032 (0.0069)	0.1319* (0.0736)
Poultry	0.0571*** (0.0083)	0.1489*** (0.0252)	-0.041*** (0.0075)	0.1618** (0.0798)
ρ_{4d}	3.4031*** (0.0631)	6.0959*** (0.1292)	-1.7864*** (0.0585)	-8.8409*** (0.8924)

Robust standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

Table 3.13 Elasticity Estimates of the Fourth Stage QUAIDS

		Seafood	Red Meat	Poultry
μ_{I_4}		1.423	1.042	0.681
ϵ_{UP_4}	Seafood	-0.963	-0.168	-0.048
	Red Meat	-0.098	-0.805	-0.175
	Poultry	0.017	-0.027	-1.069
ϵ_{CP_4}	Seafood	-0.814	0.463	0.450
	Red Meat	0.011	-0.342	0.190
	Poultry	0.088	0.285	-0.831

Source: Own calculations

In the fourth stage, the fitted meat expenditure shares acquired by the first equation of the QUAIDS are multiplied by the total food expenditures to obtain fitted meat expenditures and estimate Equation 3.24. In this stage, $\alpha_{0_4} = min\left[\widehat{ln(M_h)}\right] = -.85$, and $\sum\alpha_{i_4} = 0.898$**.** The expenditure share of seafood is exponentially increasing with the deflated meat expenditures as both β_{i_4} and λ_{i_4} are positive and significant. It is also increasing with its own-price and poultry prices, while red meat prices have an

adverse effect on expenditure share of seafood. Among demographic variables, only increasing ability to meet basic needs makes expenditure and price elasticities of seafood significantly more elastic, while others have adverse effects. Larger household size brings larger elasticities only for poultry. The only demographic characteristic that significantly increase elasticities for red meat is home quality.

Table 3.14 Parameter Estimates of the Fifth Stage QUAIDS

	α_{i_5}	β_{i_5}	λ_{i_5}	δ_{i_5}
Anchovy	-1.195*** (0.0368)	1.9741*** (0.087)	-0.0012*** (0.0001)	0.3538*** (0.0405)
Cultured	1.0606*** (0.0273)	1.4396*** (0.1305)	-0.0001 (0.0001)	0.2915*** (0.0173)
Other	0.4745*** (0.027)	-3.4137*** (0.1757)	0.0013*** (0.0002)	-0.6453*** (0.0518)
γ_{ij_5}	Anchovy	Cultured	Other	
Anchovy	-0.7579*** (0.0173)	0.4875*** (0.0118)	0.2704*** (0.0148)	
Cultured	0.4875*** (0.0118)	-0.3505*** (0.0141)	-0.1371*** (0.0112)	
Other	0.2704*** (0.0148)	-0.1371*** (0.0112)	0.1333*** (0.0175)	
$\eta_{i_5 D_d}$	z_{D_1}	z_{D_2}	z_{D_3}	z_{D_4}
Anchovy	-0.0423** (0.0187)	-0.4504*** (0.0542)	-0.061*** (0.0212)	0.6441*** (0.1531)
Cultured	-0.1364*** (0.032)	-0.3932*** (0.0822)	0.0519** (0.0228)	-0.652*** (0.2357)
Other	0.1787*** (0.0409)	0.8436*** (0.1041)	0.0091 (0.0321)	0.0079 (0.292)
ρ_{5d}	-0.0413*** (0.0074)	-0.2142*** (0.0208)	0.0393*** (0.0071)	0.0741 (0.1047)

Robust standard errors in parentheses.
**** (p<0.01), ** (p<0.05), * (p<0.1).*

Table 3.15 Elasticity Estimates of the Fifth Stage QUAIDS

		Anchovy	Cultured	Other
μ_{I_5}		2.467	1.673	-1.747
ϵ_{UP_5}	Anchovy	-1.780	0.158	0.932
	Cultured	0.476	-1.527	0.216
	Other	0.305	0.369	-1.881
ϵ_{CP_5}	Anchovy	-1.352	0.299	1.202
	Cultured	0.766	-1.431	0.399
	Other	0.001	0.269	-2.072

Source: Own calculations

Table 3.13 illustrates the elasticity estimates in the fourth stage. The expenditure and price elasticities show a similar pattern as it is in the previous stage. All food groups in this stage are normal, with meat expenditure elasticities greater than unity for seafood and red meat, but not for poultry. Although uncompensated price elasticities include mixed information about the cross-price elasticities, compensated price elasticities demonstrate that the food groups are substitutes, adjusted for meat expenditure effect. Finally, all food groups are price inelastic.

The final stage has the same structure with the previous ones including three specific seafood groups. The constant of the translog price index is accepted as, $\alpha_{0_5} = min\left[\widehat{ln(S_h)}\right] = -.44$, and α_{i_5}'s sum to 0.34. The relationships with deflated expenditure are different in three seafood groups. It is concave for anchovy because $\beta_{1_5} > 0$ and $\lambda_{1_5} < 0$, significantly. A positive linear relationship for seafood group appropriate for aquaculture is observed, with significant $\beta_{2_5} > 0$, and insignificant λ_{2_5}. Finally, the share of other seafood group has a convex relationship with deflated expenditure as $\beta_{1_5} < 0$ and $\lambda_{1_5} > 0$.

The estimates γ_{ij_5} depicts that the share of anchovy decreases with its own price level, while increases with cultured and other seafood prices. For cultured seafood, it is decreasing with both own price level and other seafood prices. Finally, other seafood share increases with its own price level.

Larger household size and better home quality lead to weaker elasticities for anchovy and cultured, but stronger elasticities for other seafood. The ability to meet basic needs and increasing RTA expenditures do not affect the elasticities of other seafood. Anchovy and cultured demand elasticities are also affected by ability to meet basic needs, with significantly smaller anchovy demand and larger cultured demand with higher ability. In contrast, RTA expenditures significantly increase elasticities of anchovy demand and reduce the ones of cultured demand (Table 3.14).

The computed elasticities depicted in Table 3.15 highlights that anchovy and cultured seafood are normal goods, while other seafood is inferior. Both uncompensated and compensated own-price elasticities are larger than unity for all seafood groups. Besides, all seafood groups are substitutes to each other with or without seafood expenditure elasticities.

It is noteworthy that expenditure elasticities in each stage should not be confused with income elasticities of demand as this is a multi-stage budgeting analysis. Thus, income elasticities for each food group and subgroups can be computed by a simple backward multiplication by following the lines illustrated in Figure 3.1. Table 3.16 illustrates the income elasticities for all food groups and the signs of the cumulative effects on income elasticities. The income elasticities of food demand in second stage and demand for five food groups show that food and its main components are necessities. Meat in the third stage has an elasticity of less than unity due to red meat and poultry, which are also necessities. However, seafood and its subgroups anchovy and cultured seafood are found to be luxuries, although other seafood is an inferior good. However, backward multiplication does not imply uncompensated and compensated price elasticities due to the weak separability assumption. For example, if seafood is found to be a substitute for poultry, all its subproducts, anchovy, cultured and other seafood are also substitutes for it.

Table 3.16 Income Elasticities by Backward Multiplication

Income elasticity of demand for…	aggregate consumption	0.368
	food	0.520
	meat	0.957
	wheat	0.392
	dairy	0.482
	vegan food	0.453
	other food	0.465
	seafood	1.362
	red meat	0.998
	poultry	0.651
	anchovy	3.360
	cultured seafood	2.278
	other seafood	-2.379

Source: Own calculations

In order to interpret sequentially, the demographic effects on total and food expenditures and group expenditure and uncompensated price elasticities in initial stages are summarized in Table 3.17. For instance, in the first stage, total expenditures are linearly increasing with an additional equivalent household size by 13.6%, given certain levels of price level, income, and other demographic variables. Since the total expenditure elasticity of food expenditure is calculated as 1.413, the cumulative impact on food expenditures becomes quadratic and around 19.22% on average.

Table 3.17 Total and Food Expenditure Changes with Demographic Variables

Stage	Demographics	Effect	Size
1	**Household size**	Positive	13.6%
	House quality	Positive	31.1%
	Ability to meet basic needs	Negative	15.2%
	Restaurant, tobacco and alcohol expenditures	Positive	185.8%
2	**Household size**	Positive	16.7%
	House quality	Negative	24.3%
	Ability to meet basic needs	Positive	6.9%
	Restaurant, tobacco and alcohol expenditures	Negative	104.8%

Source: Own calculations

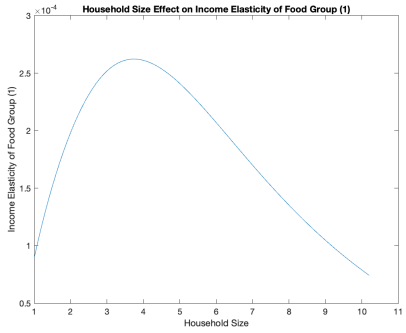
Starting from the third stage, not only the group expenditures and expenditure shares but also all elasticities are affected by the household size through a mix of linear and nonlinear combinations related parameters (η's and $\rho's$), various values of household size, and cumulative effects from previous stage decisions. Since these parameters change in both sign and size, polynomial relationships are started to be observed in following stages. These relations can be observed in all four demographic variables.

Figure 3.5a-d illustrates the four demographic effects on income elasticity of demand for meat when all prices, income level, and other demographic variables are set at their means. The income elasticity of demand for meat is highest when equivalent household size, calculated by assigning values of 1 to the first adult residing in the household, 0.5 to individuals aged fourteen years and older, and 0.3 to those younger than fourteen, is around 3.5, a value corresponding to a household consisting of at least six people. In other words, elasticity of meat is increasing as household size grows from a single adult to an example family of two parents, one grandparent, and three children that are older than fourteen or five children younger than fourteen. If the household size grows further, this elasticity declines. By neglecting rare and extensively crowded households, it can be inferred that a positive deviation in income from its mean results in a greater increase in meat demand as new people join the household (Figure 3.5a). Next, Figure 3.5b and Figure 3.6b depict that the ratio of actual household income to the minimum required income to meet the basic needs has no effect on the income and price elasticities of demand for meat if they can be computed. At some point where the ratio is around 21, they are mathematically undefined. Figure 3.5c and Figure 3.5d show that income elasticity of demand for meat

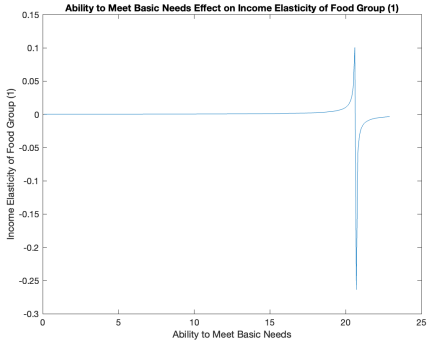
is declining among the households living in better houses and more intense consumers of restaurant, tobacco and alcohol.

Figure 3.5 Demographic Effects on Income Elasticity of Demand for Meat and Seafood

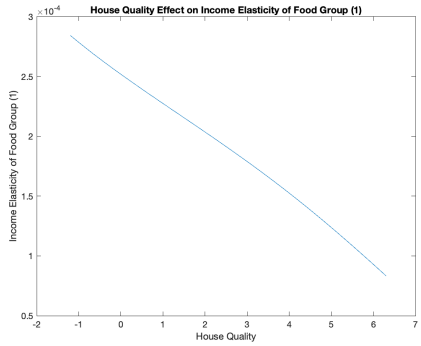
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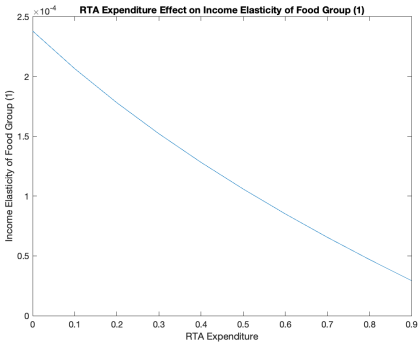
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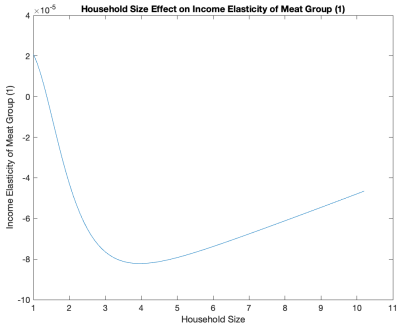
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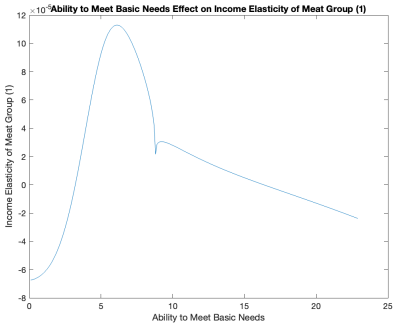
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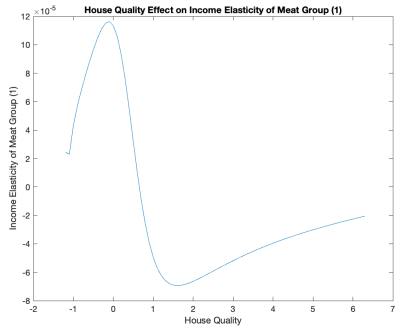
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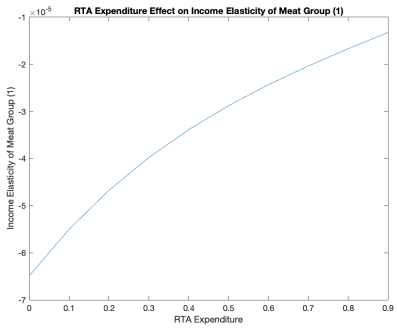
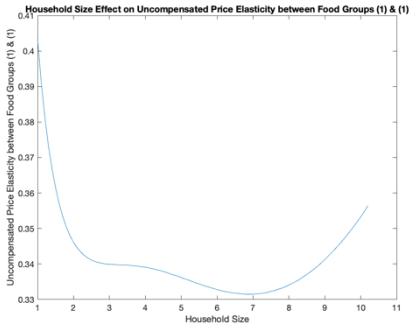
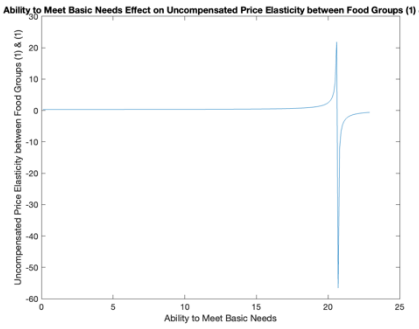


Figure 3.6 Demographic Effects on Uncompensated Own Price Elasticity of Demand for Meat and Seafood

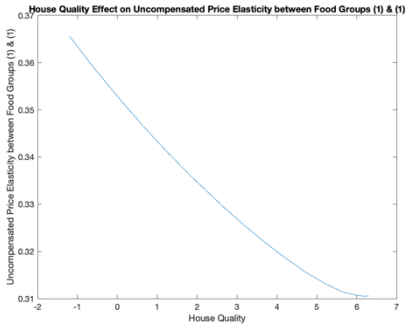
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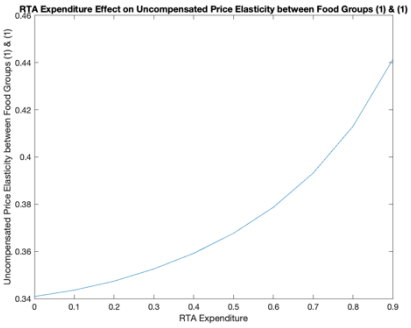
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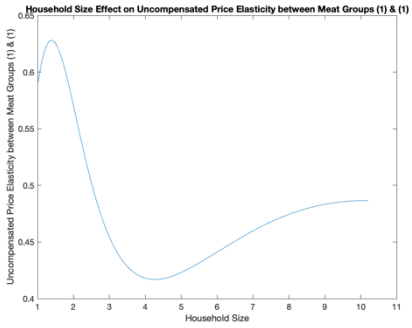
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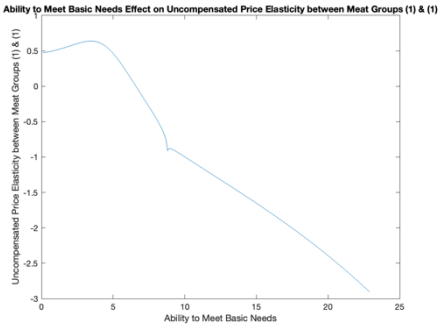
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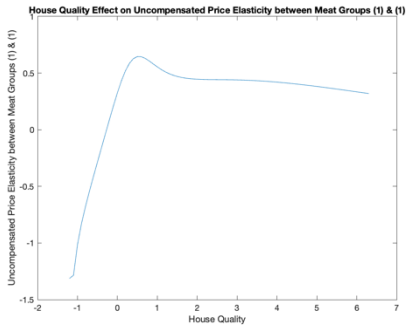
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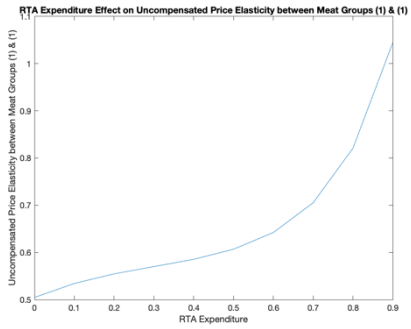
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In the next stage, neglecting very large households and the ones with income levels of at least five times the level that can satisfy their basic needs, income elasticity of demand for seafood, is declining with the household size, fluctuating with house

quality, and increasing with the ability to meet their needs, and increasing with RTA expenditures. That is, an increase in income results in a greater increase in seafood demand if the households are smaller, wealthier, or larger consumers of restaurants, tobacco, or alcohol (Figure 3.5e-h).

Depicted in Figure 3.6a-d, the uncompensated own price elasticity of demand for meat is adversely affected by household size and house quality. In contrast, the households that are more engaged to RTA expenditures have greater responses to meat price changes. To clarify, smaller households living in low-quality houses and making larger restaurant, tobacco, and alcohol expenditures are more possible to abandon meat expenditures as meat prices increase. In the next stage, the household size and RTA expenditure effects on uncompensated price elasticity of seafood demand have similar patterns with the price elasticity of meat demand (Figure 3.6e-h). Additionally, the households with greater needs compared to their income seem more sensitive to price changes compared to others (Figure 3.6f).

3.6 Discussion

Even though some Turkish food demand studies have categorized fish as a distinctive food group (Armagan & Akbay, 2008; Bilgic & Yen, 2013, 2014), a specific attention to Turkish seafood demand is given first time in this study. In contrast to most food demand studies based on the HBS2003 dataset, the low share of its consumption in the overall household budget is handled by applying a multi-stage budgeting approach in addition to corrections for sample selection bias.

Table 3.18 An Illustrative Comparison of Results

	Bilgic & Yen (2014)		Present Study	
	Poultry	Seafood	Poultry	Seafood
Poultry	-1.485	-0.092	-0.831	0.088
Seafood	-0.113	-1.660	0.450	-0.814
Expenditure	0.881	0.972	0.681	1.423

Despite the popularity of the systems of food demand analysis in the literature, varying approaches lead to different results. Table 3.18 presents a comparison of the most comparable results between the present and the most recent study that utilized the same data set. As poultry and seafood consumption are common in Bilgic & Yen (2014) and fourth stage in this study, these two groups are selected. Only the compensated price

and expenditure elasticities are compared as they best reflect the household perceptions of these goods.

Just as most studies based on LA/AIDS approach, Bilgic and Yen's (2014) study ignored both the possible quadratic Engel curves and the possible endogeneity that arise from the income levels in the error terms. First, their compensated own-price elasticities were larger than one, suggesting that households are highly responsive to poultry and seafood prices. Secondly, they found a complementary relationship between these two food groups. Finally, their results illustrated that both are necessities with expenditure elasticities less than unity. However, with all the arguments of the present study, a more superior approach shows that their findings overestimated own-price elasticities for poultry and seafood, which are less than unity. Furthermore, it is shown that poultry and seafood are not complements but substitutes, which is a more intuitive result than the previous finding. Finally, in contrast to their findings, seafood is found to be a luxury good.

In addition to the unique use of HBS2003 data set to analyze seafood demand, despite the similarities with many studies in the literature, the approach in this study involves many novel characteristics. To begin with, this study combines a popular technique for handling censored dependent variables and a much less popular demographic scaling technique. The first one is vital as it not only corrects for sample selection bias but also saves all observations in each stage. The significance of the other is more about the interpretation of demographic effects. The popular translation technique informs about the effects of demographic variables on expenditure shares; however, the coefficients on them are not included in the elasticity formulas. On the other hand, the signs of scaling parameters directly inform about the size of the responsiveness of various household characteristics.

Another novel aspect of the study lies in the design of stages. By assuming weak separability, households' decision tree is constructed in five stages. In the first stage, price-taking households having certain levels of disposable income and some demographic characteristics decide how much to spend or save. This stage is unique to this study and highly crucial as it is the only possible one during which households decide with the given values. The predicted values for the dependent variables in each stage are obtained to be instrumented in the next stages, so that the exogeneity in the first stage is transferred to next stages. Next, this study classifies seafood as one of the

animal meat groups, which also includes red meat and poultry. The decision tree ends up with the three distinct seafood groups, classified by seeking the nature of production and Turkish consumption habits. As anchovy itself constitute a large part of the seafood consumption, it is not composed with another. Besides, although their source is not known in the data set, the seafood that have been produced in Turkish aquaculture facilities are composed in in one group. Finally, the remaining ones are composed in other seafood.

Lastly, to avoid complexity, demographic and socioeconomic characteristics are limited to four variables, household size, house quality, ability to meet basic needs, and RTA expenditures, in the OLS and QUAIDS estimations during each stage. However, many other demographic characteristics are also utilized to support the analysis. For example, the house quality, considered as a proxy for life quality, is obtained by the predicted values of the rental value of the house, as a function of six different variables. This helps to create a variable that controls for the quality component of the choices. In this case, the use of quality-adjusted prices become unnecessary. Additionally, the corrections for sample selection bias are conducted through forty different variables that may affect the probability of consuming each food group.

Some behavioral implications can be obtained by the initial OLS estimations. The first stage results indicate that total household expenditures are not very sensitive to income but highly responsive to price level. In other words, households with larger income levels do not proportionally increase their expenditures but have a higher intensity to save. Besides, they can easily switch to cheaper price levels because they have plenty of consumption options. Although demographic characteristics do not affect elasticities in this stage, they can inform about the expenditure segments. Larger household size, better houses, and lifestyles including RTA expenditures are associated with significantly larger expenditures in contrast to the high ability to meet basic needs. Keeping all others constant, more competent households in fulfilling their minimum life requirements reduce their expenditures.

In the second stage, food expenditures are highly reactive to total fitted expenditures but less sensitive to price level and income. The households that spend more are more predisposed to make food expenditures than other expenditures while more expensive food baskets do not proportionally change their food consumption habits. Households

that are more populated and capable of satisfying their needs spend a greater amount on food compared to other goods, whereas those who reside in more luxurious homes, dine out, and consume tobacco and alcohol do otherwise.

From the third to the terminal stage, most food groups follow similar properties with some important exceptions in terms of their elasticities. The third stage illustrates that all goods are normal and necessities with income elasticities between zero and one. Among them, animal meat, including seafood, red meat, and poultry is the group with the largest income elasticity. Additionally, all own-price elasticities are negative and less than unity, indicating low sensitivities to price changes for all food groups. That is, one per cent increase in the price level of one of the food groups results in a decline in its consumption by less than one per cent. Moreover, each food group is a complement to another in actual consumption, but they are substitutes when income effects are removed. Stated otherwise, an average household consume all food groups together with its income during the survey month; however, these goods can be replaced with each other to keep its utility in a certain level.

In the fourth stage, seafood and red meat are luxuries in contrast to poultry, which is a necessity, and the own-price and cross-price elasticities have similar patterns with the ones in the previous stage, except that the representative household is highly sensitive to poultry prices. Finally, anchovy and seafood that can be produced in aquaculture are luxuries while others are inferior with a negative expenditure elasticity. Each seafood group is substitute to another both with and without income effects and own-price elasticities for all seafood groups are larger than one, indicating high sensitivity to price changes.

Beginning from the third stage, all four demographic variables influence the elasticities through both linear and nonlinear combinations of associated parameters, varying values of demographic variables, and the cumulative effects of decisions made in previous stages. An increase in income above its average value results in a greater rise in the demand for meat, especially when new individuals become part of the household. The income elasticity of demand for meat is decreasing among households residing in higher-quality residences and those who are more frequent buyers of restaurants, tobacco, and alcohol. Moreover, when prices for meat increase, it is more possible for smaller households residing in low-quality houses and allocating a greater

budget towards restaurants, tobacco, and alcohol to decrease their expenditure on meat.

The income elasticity of demand for seafood decreases as household size increases, varies with house quality, increases as the ability to meet needs improves, and rises with RTA expenditures. Specifically, a rise in income leads to a greater flow in the demand for seafood when households are smaller, wealthier, or have a higher consumption of restaurants, tobacco, or alcohol. Besides, the impact of household size and RTA expenditure on the uncompensated price elasticity of seafood demand is comparable to that of meat demand. Nevertheless, households that have greater requirements in proportion to their income exhibit a greater degree of sensitivity to fluctuations in prices.

These findings have the potential to enhance understanding of the causes of inadequate seafood consumption in Turkey. Its consumption is less stable than that of other protein sources due to its high own-price elasticities, which demonstrate household sensitivity to price fluctuations. Furthermore, aquaculture-produced seafood and anchovies are mainly classified as luxuries, which implies that they are less accessible to individuals with lower incomes. Consequently, most households allocate their consumption to red meat and poultry, which serve as substitutes for more costly seafood, when the price elasticity is adjusted for income effects. The inferiority of the other combined seafood is likely due to cultural factors in Turkish cuisine, as they are not significantly less expensive than aquaculture-produced fish and anchovies, and their expenditure share is not as high as that of anchovies.

More crowded households are less likely to increase their consumption of seafood as their incomes increase and are less responsive to price changes, excluding overcrowded households. This suggests that they are less likely to consume seafood. Similarly, households that reside in homes of inferior quality are less receptive to fluctuations in prices. However, they are more inclined to consume seafood if their income increases than individuals residing in medium-quality housing. The sole certainty is that individuals residing in high-quality residences consume a greater quantity of seafood as their incomes increase, and they are not influenced by price fluctuations. Consequently, low fish consumption may be linked to substandard housing quality. The situation is comparable for households that encounter challenges in satisfying their fundamental requirements. As the income/need ratio decreases,

households that earn less than five times the amount necessary to meet their basic needs are less likely to consume seafood. Likewise, their responses to price fluctuations are also lower. Lastly, households that make lower total restaurant, tobacco, and alcoholic beverage expenditures are also less susceptible to fluctuations in income and prices. Consequently, they are also less inclined to consume seafood.

These findings are in accordance with the observations in Knudsen (2009). He suggested that dining out on seafood is a luxury in Turkey. The urban upper and upper-middle classes are typically the demographic that visits fish restaurants, which are quite rare. The elite view seafood with alcohol as a symbol of a wealthy, secular lifestyle and a sophisticated and elegant way to start a nice conversation in a private setting. For some, fish should be consumed with alcohol, in order not to make it die filthy and sad. Even though seafood culture is mostly seen in restaurants and tourism, it is also a luxury consumption when eaten at home. Some types of seafood are sold with a price higher than red meat. As a result, serving fish at home or another organization are mostly be interpreted as a special occasion in Turkey.

3.7 Conclusion

Overall, most of the seafood consumption in Turkey is associated with a luxurious lifestyle. The main reasons for this are various cultural and economic segments of the population and the limited availability of seafood in the domestic market. Current subsidization of aquaculture that produce luxury seafood could potentially enhance their accessibility in the Turkish markets. Nevertheless, this may not be sustainable due to a variety of natural factors, including sprat and anchovy stocks and increasing feed prices. In addition, the production processes in the aquaculture require large amounts of anchovy, which is a type of seafood culturally preferred in Turkish cuisine. Its reduction as a final consumption good should be compensated by an increase in the cultured seafood sold in domestic markets. Moreover, due to expanding exports, domestic consumers must compete with the rest of the world that have greater willingness to pay for seafood. As a result, seafood consumption remains a luxurious practice for most of the population.

Thus, the measures to increase seafood consumption in Turkey should include two main purposes. First, the amount of seafood in Turkish seafood market should be increased. Specifically, there is a need to increase the availability of anchovies in the

market at affordable prices for households, rather than solely using them as an ingredient to produce more expensive products. To achieve this objective, it is necessary to impose limitations on the sale of anchovies to fish meal and oil factories. Furthermore, it is imperative to promote the sale of cultured fish in the domestic market at more accessible prices, even though they are primarily produced using imported inputs. Additionally, it is crucial to provide support to sellers in order to facilitate this endeavor. Exporting aquaculture products that are not suitable for Turkish cuisine, while marketing the species that can be consumed locally, will greatly increase consumption in the domestic market, despite their scarcity in Turkey.

Secondly, seafood should be positioned as a necessity rather than a luxury item. In Turkey, coastal areas and nearby locations are the primary regions where seafood is predominantly consumed. These regions have historically attracted secular and affluent populations, in addition to being well-suited for maritime tourism. Consequently, seafood is frequently offered in high-end dining establishments in the country as an accompaniment to alcoholic beverages, making it a distinctive cultural characteristic. Despite the recent growth of inland waters aquaculture, the areas away from coasts still lack a well-established culture of seafood consumption. A considerable proportion of fish caught and farmed is ultimately used for luxury restaurant or foreign consumption. As a result, this fish finds its way into markets and grocery stores, resulting in limited consumption options for a significant portion of the population.

Therefore, the awareness campaigns should focus on these problems not only by highlighting its nutritional benefits and emphasizing the importance of consuming it at least twice a week but also addressing strategies for ensuring the availability of seafood and provide guidance on how the households should incorporate it into their diet including their conservation and cooking techniques. In addition, the government should develop additional subsidy and support programs to ensure more affordable seafood prices for crowded households with lower income struggling to meet their basic needs. Finally, establishments of more effective logistic networks and formations of strong collaboration with local fishermen and aquaculture producers are crucial to ensure the widespread distribution of seafood across the entire geographical area.

Although this study offers significant insights regarding an appropriate analysis of food demand and estimates the parameters of Turkish seafood demand, it exhibits

some limitations. As the choice of methodology requires detailed knowledge about prices and quantities, the analysis is based on a relatively old survey conducted in 2003. More recent datasets provided by TurkStat include total consumption values for more aggregated consumption items rather than disaggregated information on prices and quantities. Thus, as long as such a detailed dataset, including commodity prices faced by households, quantities consumed, and household characteristics, is not present, alternative methodologies applicable to current datasets should be developed.

Alternative datasets including average group prices can be incorporated next to the total consumption values by ignoring the fact that households face different prices. Such an analysis might reflect the general trends in current food consumption. However, some methodological innovations, including alternative definitions for the utility function and developing quality-adjusted prices and quantities based on household segments, might be necessary.

4 BIOECONOMIC MODELING OF SEASONAL CLOSURES, FISH MEAL AND FISH OIL FACTORIES' SHARES, AND FISHING CAPACITY IN TURKEY

4.1 Introduction

A well-structured examination of Turkish fisheries policy necessitates a precise identification and placement of its regulatory framework within the fisheries management literature. Reimer & Wilen (2013) explain a widely accepted classification of fisheries management regimes based on the historical development of technological, institutional and regulative structures. The open-access regime is historically the oldest, marked by undeveloped markets, inefficient technologies, and, as pointed out in Gordon (1954), rent dissipation due to overexploitation. Still, before fisheries have become industrialized, these problems were not substantial.

With technological advancement and commercial expansion, marine resources have increased value, prompting investment incentives in fisheries. Provided that resources are sufficiently available, and fishing activities provide profitability, an open-access system permits free entry; nonetheless, the economy ultimately encounters an overfishing dilemma, resulting in increasingly insufficient marine biomass and gradually declining earnings. This encourages the absorption of transaction costs through a shift towards institutional transformation and an active regulatory framework.

The initial regulations against the symptoms of the open-access regime include gear restrictions, local closures and seasonal fishing bans; however, units remain free to enter. Homans & Wilen (1997) named this regime as regulated open-access (ROA). Although ROA regime has provided some benefits, fisheries remained even more profitable and attracted further entries. This has necessitated much shorter fishing seasons, making the control on effort and fishing mortality more difficult.

Eventually, some fishing authorities have started to replace nonexcludable ROA regime with regulated restricted access (RRA) regime which is characterized by an

additional restriction based on fishing licenses. Reimer & Wilen (2013) characterize RRA with limited input (number of vessels or capacity). Based on this definition, although it is a solution to the free entry problem, a new phenomenon called 'rule of capture', which can be defined as a principle that any fishing unit in the fleet capturing some fish acquires its possession, arises. In this case, 'race to fish' remains among fishing units leading to more intensified effort with more advanced technology and fishing 24 hours a day. As a result, the maximum determined amount of any species that can be captured by the remaining vessels during a fishing period, or total allowable catch (TAC), can be harvested in very short times. While establishing the total allowable catch and limiting fishing capacity offers certain advantages, the reality that the fishing season is often far shorter than expected — occasionally condensed to within a few days — presents new challenges.

Recently, in response to harmful economic incentives, fisheries institutions in some countries have initiated a shift to a rights-based management of fisheries. The initial rights-based systems introduced individual transferable quotas (ITQs), clearly defined property rights for fishing units over shares of TACs. Thus, the incentives of fishing units shift from maximizing their catch levels to maximizing the value of their share. Recently, several systems have distributed shares to entities like fishing cooperatives, while others assigned rights to specific geographical zones where species populations are found. Still, ITQs do not confer property rights over the fish populations, allowing the 'rule of capture' to remain in effect. Table 4.1 presents a summary for the classification of fisheries regimes.

Table 4.1 Classification of Fisheries with Their Main Features

Open-access systems	No regulation
Regulated open-access (ROA) systems	Regulation without limited entry
Regulated restricted access (RRA) systems	Regulation with limited entry
Rights-based systems	ITQs

According to Waldo et al. (2016), an implementation of ITQs is compulsory but not adequate to attain maximum economic yield (MEY). First, an individual quota system must be transferable without any limitations. Thus, individual nontransferable quotas in Sweden and ITQs with limited transferability in Norway are classified under RRA systems. Moreover, even though ITQ system is implemented, decades may be necessary for its adjustment to the MEY equilibrium. Thus, in Denmark that uses ITQs

since 2007, RRA is still applied. Furthermore, since ITQs are implemented in Iceland since 1980s, it can be defined as an MEY fishery. However, as gear restrictions and season length regulations are also present, there are still some open-access externalities.

Dupont (1990) enumerates three sources of rent dissipation in restricted access fisheries. First, capital stuffing may occur as a result of input substitution, when fishing units expand their captures by altering their input compositions from restricted to others. Fleet redundancy is an additional source of rent dissipation, even within restricted access fisheries. It may emerge when the regulator allows an excess of the ideal number of vessels to engage. The last source is an inadequate combination of diverse vessels. Government-mandated total catch allocations for each vessel type may allow less efficient boats to persist in fishing activities.

In contrast to classical theories that considers perfectly malleable capital in fisheries, Clark et al. (1979) define "non-malleability" as the presence of limitations on the divestment of capital assets employed in the utilization of resource stocks. In fisheries, a capital investment like a fishing vessel is frequently designed for a pre-determined purpose and cannot easily be repurposed or sold at least in its initial value. Their findings with static parameters indicate that capital limitations lead to overcapacity in the short term, when excess capital exists relative to the resource. Over time, the system adjusts through depreciation, converging to a long-run equilibrium with optimal sustained yield. They also conclude that when the malleability of physical capital decreases, it becomes increasingly more essential for a biomass to be significantly reduced before extreme stock rehabilitation measures, such as fishing moratoria, may be optimal.

Rust et al. (2016) present a dynamical model with quasi-malleable capital and myopic expectations to analyze how excess capacity arises. They highlight the significance of formulating effective capacity management policies that extends beyond scenarios where fishing regulations are inadequate or ineffective, illustrating that competitive incentives for fishing and investment persist among fishers across various regulatory frameworks, including individual transferable quotas. Moreover, since fishing units may shift their actions to unregulated regions, the management should be in sectoral and multi-species level rather than focusing on individual fisheries.

The characteristics of Turkish fisheries management as outlined in Circular No. 6/1 (Resmi Gazete, 2024), can be contextualized within the existing literature. It incorporates a controlled open access regime (ROA) due to the implementation of a seasonal shutdown for large-scale fishing from April 15 to August 31. Large-scale units account for a significant proportion of overall yearly catches, whereas off-season catches by small-scale units are minimal, making this situation extremely comprehensible. Still, around 20% of the overall fishing capacity is allowed to remain operational during the seasonal shutdown. Additionally, several gear-, species-, and region-specific regulations exist, including mesh size, catch size limitations, and marine protected areas, which are categorized under ROA.

Table 4.2 Number of Vessels by Size (Meters) Group

Year	5 - 7.9	8 - 9.9	10 - 11.9	12 - 14.9	15 - 19.9	20 - 29.9	30 - 49.9	Total
2014	9508	3064	621	392	286	489	227	14587
2015	9558	2978	451	373	277	463	232	14332
2016	9416	3009	642	434	278	475	239	14493
2017	9237	3068	678	488	289	484	229	14473
2018	8969	3127	605	492	290	434	248	14165
2019	8904	3086	634	500	287	437	241	14089
2020	8747	3301	688	514	290	448	251	14239
2021	8673	3311	725	516	294	451	245	14215
2022	8541	3341	729	492	279	430	248	14060

Source: *TurkStat Central Dissemination System (MEDAS)*

Secondly, the necessity of a fishing license for participation in fishing activities indicates a regulated restricted access (RRA) regime. Nonetheless, as seen in Table 4.2, while the total number of vessels is capped at a certain limit, the number of vessels measuring at least 10 meters has risen by around 8.1%, and overall capacity in gross tonnage has similarly grown (Table 4.3). Furthermore, most fishing units in the TurkStat Fisheries Micro Data Set indicate that their daily average working hours are under 24 and their monthly working days are fewer than 30. Additionally, they alter their gear type and target species throughout the season, resulting in a significant portion of their capacity remaining unutilized. Consequently, capital stuffing, fleet redundancy, and overcapacity are prevalent issues that Turkish fisheries management must address. Consequently, the evolving fleet composition and idle capacity indicate that fishing licenses in Turkey fail to regulate fishing capacity and restricted access does not hinder the potential increase in effort within the fishery.

Finally, there are species subject to annually determined quota levels. Among those, turbot (scophthalmus maximus), Atlantic bluefin tuna (Thunnus thynnus), baby clam (chamelea gallina), sea cucumber (holothuroidea), and eel (anguilla anguilla) have already been subject to quota in Circular No. 5/1 (Resmi Gazete, 2020). However, as their shares are very low compared to total catch levels. Moreover, eel eel (anguilla anguilla) is not a subject of marine capture fisheries as it is found in inland waters. Lately, the most significant species in Turkey, European anchovy (engraulis encrasicolus), has been added to the new document for the first time, and its total quota level is determined as 400000 tons for 2024-2025 fishing season.

Table 4.3 Number of Vessels by Tonnage Group

Year	1 - 4	5 - 9	10 - 29	30 - 49	50 - 99	100 - 199	200+	Total
2014	11451	1602	642	266	310	213	111	14587
2015	11712	1092	578	253	330	242	133	14332
2016	11782	1099	598	251	356	279	136	14493
2017	11558	1218	700	273	352	257	121	14473
2018	11223	1268	725	271	343	236	102	14165
2019	11027	1329	752	271	342	247	124	14089
2020	10909	1480	832	269	331	278	144	14239
2021	10905	1432	831	267	349	285	151	14215
2022	10737	1533	799	238	321	262	174	14060

Source: *TurkStat Central Dissemination System (MEDAS)*

According to the Instruction on the Implementation of Quota and Production Planning in Anchovy Fishing, from 01 September 2024 to 14 April 2025, individual nontransferable quotas has been allocated to 661 fishing vessels based on their lengths and gear types (TOB, n.d.). Although it is a key development for transition to a rights-based fisheries management, the total quota level for anchovies exceeds the 273914 tons caught in 2023, the peak level in the past decade. Another significant measure is that no more than 50% of the anchovy catches can be sold to fishmeal and fish oil factories except the ones in the Marmara Sea, where it is forbidden to sell to them in bulk.

Overall, fisheries management regime in Turkey is under a transition period between regulated open access (ROA) and restricted regulated access (RRA) systems (Table 4.4). The barriers on entry are not sufficient and property rights that cover only a few of numerous species only allows for a right to use of stocks as public goods. With its

seasonal closures, gear restrictions, catch size limits, and regional measures, Turkish management system is best characterized by the regulated open access (ROA).

Table 4.4 Turkish Fisheries in Terms of Fisheries Management Regimes

System	Key features	Problems	Turkey
Open access	No control on effort or entry Common pool resources	Rent dissipation Overcapacity Overfishing Resource depletion	Not present
Regulated open access (ROA)	Seasonal closures Gear restrictions Size limits No control on entry Limited conservation	Race to fish Overcapacity Rent dissipation Overfishing Resource depletion	Seasonal closures for large-scale fisheries Gear restrictions Size limits Regional measures
Regulated restricted access (RRA)	Limited number of licenses Total allowable catch (TAC) Moderate conservation Partly recovered rent	Race to fish Rent dissipation Overfishing Resource depletion	Licensing is present without addressing overcapacity Fleet redundancy Capital stuffing
Rights-based (hybrid)	Limitedly transferable individual quotas Right to use of stock as public goods Partly recovered rent	Rent dissipation	Individual nontransferable quotas for limited number of species
Rights-based (MEY)	Individual transferable quotas Maximum economic yield		Not present

Once the fisheries management regime and its challenges in Turkey is positioned based on the concepts in the literature, this study develops a bioeconomic model portraying the status of Turkish fisheries under its present regulatory structure and a set of policy options in order to search for regulations that increase welfare and protect natural resources. To this end, by employing a deterministic infinite horizon decision model, welfare effects of different policy combinations, including season length, capacity utilization, and FMFO shares, are compared under optimal behaviors of the large-scale fishing units. In order to evaluate policies, a maximum sustainable yield (MSY) rule is followed without neglecting the affected welfare levels of various agents.

The remainder of the Chapter 4 is organized as follows: Section 4.2 presents a review of the relevant literature. Then, Section 4.3 explains the analytical model employed in the analysis. After Section 4.4 explains the parameters used in the calibration, Section 4.5 presents, and Section 4.6 discusses the results. Finally, Section 4.7 concludes.

4.2 Literature Review

The literature on the economics of fisheries management and policy is quite extensive and still developing with its multi-disciplinary nature and new issues like alternative management strategies, new technologies, and rapid growth of aquaculture. First, there are studies that identify the fundamental problems about analysis of fisheries management and policy. Wilen & Homans (1998) have addressed that an effective governance system must align with both scientific facts and political conditions. They have developed a partial adjustment model that considers the divergence between the desired season length established by regulators and the actual season length, with actions used to only partially resolve this mismatch. They have asserted that a significant element contributing to the overfishing of several worldwide fisheries is the compliance of regulators to immediate economic pressures. Thus, the effectiveness of legislation depends on reconciling biological sustainability with economic sustainability. Next, Smith (2012) have presented an extensive examination of modern fisheries economics, stressing the operation of incentives across several dimensions, including seasonality, species selection, regional distribution, and market dynamics. He has argued that while traditional models focus on the commons issue, modern approaches must incorporate broader economic and ecological relationships to improve fisheries management outcomes.

Asche & Smith (2018) have optimistically analyzed the influence of induced innovation in fisheries and aquaculture, positing that scarcity encourages technological, regulatory, and market changes. They have argued that although Malthusian theories forecast resource exhaustion, the seafood sector has adapted through innovations in aquaculture, selective breeding, and fisheries management. Thus, innovation in these sectors may relieve scarcity, postponing or maybe averting the depletion of resources. Wilen (2006) has emphasized the inadequacy of the traditional fisheries management strategies, promoting well-defined rights-based systems that can synchronize economic incentives with environmental objectives. On

the other hand, Cunningham et al. (2016) have investigated policy spillovers in regional fisheries management, specifically analyzing the impact of catch-share programs. By employing a difference-in-differences methodology, they have identified an evidence of effort leakage, when fishermen redirected their efforts to unregulated or less controlled fisheries. Their research has underscored the unanticipated results of regional management choices.

Ertör & Ortega-Cerdà (2019) have investigated the growth of intensive marine aquaculture in Turkey as a different frontier in global seafood production. Their research has contended that aquaculture reflects the historical growth patterns of industrial capture fisheries via horizontal (geographical), vertical (depth of waters), and taxonomic (species range) expansion. This expansion has shifted Turkey's seafood output from wild capture to aquaculture, propelled by international demand and the ecological constraints of capture fisheries. They have examined the social and ecological consequences of this transition and emphasized how aquaculture companies utilize techniques of product expansion, enhancement, and promotion to secure demand for intensively cultivated seafood. Naylor et al. (2009) have examined the impact of aquaculture on capture fisheries, analyzing changes in the utilization of fishmeal and fish oil. Despite the reduction in fishmeal inclusion rates in aquaculture, overall consumption has risen due to increasing aquaculture output, particularly for species rich in omega-3 fatty acids. They have proposed that regulatory incentives may accelerate the shift towards non-fish alternatives, so enhancing the sustainability of both fisheries and aquaculture.

Secondly, there are studies that examine controlled open-access policies, including constraints on season length. Homans & Wilen (1997) have proposed a model for regulated open-access (ROA) resources that determines seasonal lengths based on a safe quota level aligned with industry capacities. Anderson (2000) have expanded the Homans-Wilen paradigm by introducing a dynamic model of open-access fisheries with endogenous regulatory mechanisms. The research has evaluated the effects of season length, trip limit, and aggregate quota policies. Although the models in these studies are well-defined in terms of inter-season dynamics, they have ignored the intra-season dynamics. There are also studies that are built upon these. For example, Da Rocha & Gutiérrez (2012) have developed a stochastic model to analyze the application of total allowable catch (TAC) regulations alongside season lengths. In a

stochastic framework, they have examined the optimization of regulatory control mechanisms in situations when stock levels are not precisely quantifiable. Their findings have demonstrated that the incorporation of TACs improves both biological and economic outcomes, especially in large-scale fisheries, by prolonging the optimal season length and reducing extinction risk. Moreover, research has demonstrated that an expanded fleet leads to increased escapement levels when TACs are enforced, in contrast to rules based only on fishing seasons. More recently, a model that accounts for seasonal variations has been suggested by Kvamsdal et al. (2020). Their model has included periodicity in fishery features, showing that considering seasonal fluctuations enhances management outcomes. They have also demonstrated that failing to incorporate seasonality into regulatory measures can lead to economic inefficiencies, including poverty traps.

Third, there are studies that focus on the behaviors of fishing units and regulators. Kvamsdal (2010) has presented a comprehensive review of empirical research about fishing units' adaptations to new laws. The research has indicated that their behavior is shaped by economic, biological, and social variables, resulting in unforeseen outcomes of regulatory modifications. The research examines instances when legislation intended to restrict fishing effort led to technology innovation or effort relocation, highlighting the intricacies of fisheries management. Hoffmann & Quaas (2016) have examined the role of common-pool politics in the inefficacy of fisheries management, particularly on the establishment of TACs. Employing a dynamic game-theoretic model, they have illustrated that decision-makers motivated by short-term incentives are inclined to advocate for overly elevated TACs, resulting in overexploitation. They contend that obligatory commitments to long-term management strategies might improve sustainability. Libecap (2024) has recently examined the disparities in state reactions to open access fisheries, highlighting the impact of sector structure, resource valuation, and political dynamics on regulatory results. The study has observed that regulatory efficacy is contingent upon constituent attributes, with affluent and politically organized sectors more inclined to get advantageous regulations. Finally, Sun et al. (2024) have examined the collaboration between governments and fishermen in enforcing fishing limits for ecological restoration. The study has used an evolutionary game model to examine compliance behavior and adaptive tactics among fishermen. Research has indicated that the

efficacy of policy is contingent upon economic incentives, enforcement strategies, and stakeholder involvement.

Knudsen (2004) have revealed the historical development of fisheries management in Turkey and the neglect of traditional fishing techniques. From Ottoman times to current Republican period, the study has observed a transition from a regionally regulated and tax-oriented fisheries to centrally managed modern fishing industry. This has resulted in several social, environmental and economic challenges, such as overexploitation, increased inequality in income distribution among fishers, disappearance of traditional fishing techniques mainly used by locals, and increased dependance of state policies. Similarly, Ulman et al. (2013) have summarized Turkey's marine fishing history. Since the 1930s, the national catch volume has risen, with species like bonito and Atlantic mackerel being harvested during this period. The fishing industry in Turkey has expanded significantly since the early 1950s due to enhanced industrial practices and technical innovations. This advancement has led to overfishing and environmental deterioration. Substantial declines in fish populations due to overfishing and ecological disruptions prompted the adoption of novel management and conservation measures, especially in the Black Sea, by the late 1980s. The shift to a market-oriented economy in the 1980s, along with heightened government involvement in the fishing sector, has led to significant changes in Turkish fishing practices. This era witnessed substantial growth in anchovy fishing, becoming it a crucial sector of the national economy. Due to the reduction in demersal fisheries from overfishing, several bottom trawl boats started targeting tiny pelagic species in the 1990s. Between 1950 and 2010, Turkey's marine fishing species composition has undergone significant alteration due to advancements in fishing methods and technology, transitioning from larger, more profitable fish to smaller, less value species. Lately, the expansion of aquaculture in Turkey has led to an additional disadvantage for fishing units that have to compete with the cultured seafood in the market (Ertör & Ortega-Cerdà, 2019).

In recent years, some studies in Turkey have used economic data sets along with the biological and environmental indicators. Some of them directly addresses the seasonal closures in fisheries. Yıldız et al. (2020) have evaluated the efficacy of Turkey's seasonal fisheries closures by examining market landings during fish breeding periods. Although closures effectively save certain species, others continue to be at risk owing

to winter spawning or small-scale fishing activities. The study has advocated for the addition of real-time closures (RTC) focused on species that are extensively fished during their breeding seasons, alongside industrial closures, to improve conservation initiatives. Moreover, illegal fishing remains as a significant issue; thus, inspections must be augmented, and the operations of fishing vessels should be monitored by vessel monitoring systems (VMS). Demirel et al. (2023) have examined the effects of regional sea warming and landings on small and medium pelagic fisheries in the Marmara Sea. They have found that pelagic fisheries in the Marmara Sea exhibit significant seasonality and are influenced by sea surface temperature, fishing pressure, and food chain dynamics. Moreover, the fishing season for anchovy, sardine, and horse mackerel has been shortened, with fishing pressure focused on certain months. They have recommended to establish adaptive solutions in fisheries management and postpone the commencement of the fishing season by 45 days. Finally, Dereli et al. (2024) analyze fleet compositions and species-specific regulatory frameworks in the Aegean Sea, contrasting fisheries management practices between Greece and Turkey. The research has indicated that inconsistencies in conservation reference sizes and closed seasons between the two nations underscore the necessity for unified legislation. There is also another study that specifically focuses on the determinants of seafood prices in Istanbul Fish Market. Yildiz et al. (2023) have examined bioeconomic indicators at the Istanbul Fish Market, concentrating on fish size, landings, and market prices. Two findings of this study are especially important. First, the maximum catch size of species has been found to be a more significant determinant on pricing then the level of landings. This highlights the necessity of more detailed data sets then the ones that ignore biological and environmental factors. Secondly, it has been claimed that seafood market conditions are predominantly determined by the commissioners that have significant power on the prices. Thus, they have suggested that cooperative structures where fishing units can sell directly should be supported. On the other hand, the present study argues that fish meal and fish oil companies exhibit even much more market power than the commissioners in determining the prices.

Another significant aspect of the literature on economics of fisheries management is that it includes various modelling techniques. The utilization of agent-based models (Scott, 2016), optimizing the net present value of ecosystem services (Tan & Jardine,

2019), multi-cohort Beverton-Holt models (Da Rocha et al., 2013), models for spatial fisheries management (Akpalu & Vondolia, 2012), and dynamic optimization models (Ni & Sandal, 2019). Among these approaches, the multi-season, multi-state dynamic optimization model for fisheries management proposed by Ni & Sandal (2019) is the closest method to the one in the present study. Their methodology has used dynamic programming to ascertain optimal harvesting strategies throughout several seasons, illustrating that seasonal dynamics may result in natural moratoriums or marine protected zones. The model has demonstrated that optimal harvesting tactics may fluctuate seasonally, hence questioning conventional annual management approaches. Although this model is relatively advanced, it suffers from a frequently ignored but essential problem in the literature which is brought up by Jensen et al. (2019). They have criticized conventional models in fisheries economics that misinterpret the concept of welfare by focusing solely on resource rent. They have suggested a new approach that is based on consumer and producer surplus.

In this study, a discrete time, discrete state decision model is structured such that, at each period, fishing units observe the stock level in the system, performs its optimal effort, and obtain a dynamically optimized profit under current fisheries policy. The fisheries regulator has some power to determine fishing capacity, their marketing options and the season length. Once the regulator sets a policy, the fishing units acts so as to maximize their sum of discounted profits, creating the market conditions for commissioners, fish meal and fish oil factories, and consumers. The fisheries regulator aims to choose a relatively better policy combination that maximizes the social welfare, which is compounded by consumer and producer surpluses, as suggested by Jensen et al. (2019). For this purpose, this model is replicated for 112 times representing 14 different season lengths, 4 total fishing capacities, and 5 allowable shares of FMFO factories and the resulting social welfares and the stock levels.

4.3 Model

Among the features of the restricted open access (ROA), gear restrictions, catch size limitations and regional measures apply differently to many different types of gears, species and fishing zones. On the other hand, seasonal closures apply most large-scale fisheries equally. Thus, it is fair to assume that gear restrictions and catch size limitations are features of capacity use limitations that only reduce the capacity

utilization. Although the seasonal closure applies to large-scale fisheries, small-scale fisheries that that can use 20% of the total capacity can fish off-season with a significantly smaller percentage of lower catchability. Moreover, the current ineffective quota does not apply off-season. Besides, up to 50% of the anchovy catches subject to quota can be sold to FMFO factories, while almost all sprat catches are sold to them. Finally, there have been some attempts to reduce the fishing capacity through buy-back programs that fail to prevent the fisheries from the capacity increases.

In this study, large-scale fishing units responsible for the majority of the catch constitute the fishing fleet that is regulated by an authority. The regulator has a set of fishing ban policy options, each of which aim control total annual effort in different levels and determine the duration for stock recovery. Besides, the regulator can set the share of seafood sales to fish meal and fish oil (FMFO) factories. Given the initial state for each option, fishing units determine their actions to maximize their sum of discounted profits in a deterministic model. Besides, since fisheries resources are renewable, this study forms an infinite horizon model. Most parameters in the model are estimated by a monthly data set; however, the parameters arranged such that time, t, is measured in days.

The benchmark model is developed so as to reflect the current conditions with simplifying assumptions and all counterfactuals are constructed accordingly. First, it is assumed that there are only large-scale fishing units fishing during the season; thus, the fisheries are completely closed off-season. Secondly, one year is assumed to be 360 days, 135 of which are included in the fishing ban period under current conditions. In order to observe the performances of different fishing ban policies, season bans of 0 to 195 days with 15-day intervals are considered in alternative models.

In addition, to model the current situation, average of 62.5% of seafood are assumed to be sold commissioners that sell them to final consumers, while the remaining are left to FMFO factories, in line with the data depicted in Table 4.6. Then, additional counterfactual ratios ranging from 57.5% to 67.5% are considered in alternative models.

Based on the data depicted in Table 4.3, it is observed that large-scale fishing units have a total daily fishing capacity around 2100 GT-hours if they are active 24 hours a day. Since the average effort level is estimated to be slightly less than 630 GT-hours

in the micro data set, it is assumed that capacity utilization under current fishing ban policy is 30%. It seems low mostly due to the fact that most vessels have only one skipper that cannot work 24 hours a day for long fishing seasons. However, some reductions may arise from the ROA regulations that need to audit various gear uses, catch sizes and regional activities. Although it can be claimed that the capacity utilization must fall as these regulations become more intense, it is assumed that they are the same for all alternative models. On the other hand, it is assumed that capacity utilization is reduced with the season length by a coefficient of k^{ρ}, where k is the number of days in a season and ρ is a constant that is arranged to reflect the current situation. Still, alternative fishing capacities are evaluated under additional models to address the attempts for capacity reductions and technologies.

As a result, 112 discrete time, discrete state decision models (Miranda & Fackler, 2002) are constructed for 10 years simulations and they are compared in terms of welfare, market prices, and stock dynamics. The possible effects of each policy can be analyzed by a bioeconomic model of fisheries that is based on the following growth function:

$$\Delta X_{t,n} = G\left(X_{t,n}\right) - Y\left(E_{t,n}, X_{t,n}\right) \tag{4.1}$$

where $\Delta X_{t,n}$ is the change in the stock level, $E_{t,n}$ is the fishing effort in time t under policy n. $G\left(X_{t,n}\right)$ is the logistic growth function:

$$G\left(X_{t,n}\right) = rX_{t,n}\left(1 - \frac{X_{t,n}}{K}\right) \tag{4.2}$$

where r is the intrinsic growth rate and K is the carrying capacity of the biological system. In each period, the harvest, $Y_{t,n}$, is generated by Cobb-Douglas production function:

$$X_{t+1,n} = X_{t,n} + rX_{t,n}\left(1 - \frac{X_{t,n}}{K}\right) - qE_{t,n}^{\alpha}X_{t,n}^{\beta} \tag{4.3}$$

In this analysis, the state variable is the stock level that is assumed to be bounded above by carrying capacity, K, and cannot be negative. Formally,

$$X \in [0, K]$$

Given any initial state, $X = X_0$, and any fisheries policy, the fishing units determine the harvest each period which is a function of stock and effort. Thus, the action variable is the nonnegative effort level, which is bounded by the fishing capacity, $E_{max}n^{\rho}$. That is,

$$E \in [0, E_{max}n^{\rho}]$$

Moreover, the effort level in the next period is determined by the duration of the fishing season, the effort and the stock next period by the following equation:

$$E_{t+1,n} = z_{t+1,n}(\gamma_1 X_{t+1,n} + \gamma_2 E_{t,n}) \tag{4.4}$$

where $z_{t,n}$ is the binary element representing the fishing season, n is the total number of days in the season, $\rho < 0$ is the propensity parameter that fishing units perceive their fishing capacity based on the season length, and $\gamma_1 > 0$ and γ_2 are parameters scaling the impacts of the stock level next period and current effort level. When $z_{t+1,n} = 0$, fishing is prohibited in the next period, reducing the effort level to zero regardless of the current stock and past effort. If $E_{t,n} = 0$ and $z_{t+1,n} > 0$, the next effort is equivalent to a positive value determined by the stock level.

The marketing channels utilized by fishermen can be categorized into two groups. The initial category comprises buyers who will utilize the products as intermediate goods, primarily fish meal and oil manufacturing facilities. Due to their substantial purchasing, these factories mainly acquire sprat and anchovy in bulk with lower prices. The second group consists of commissioners who will sell the products directly to consumers. These intermediaries distribute the products to consumers monthly at a specified profit margin. The market price is determined by the following inverse consumer demand function:

$$p_{c,t,n} = \left(\frac{\tau_t Y_{t,n}}{A_t}\right)^{\frac{1}{\vartheta_1}} \tag{4.5}$$

where $\tau_{t,n}$ is the share of consumer goods and $A_t = \mu_t^{\vartheta_1} I_t^{\vartheta_2} p_{b,t}^{\vartheta_3} p_{c,t}^{\vartheta_4}$; μ_t is commissioners' mark-up, I_t is income, $p_{b,t}$ is beef price, $p_{c,t}$ is poultry price at time t, and ϑ_1, ϑ_2, ϑ_3, and ϑ_4 are elasticity parameters. Here, $p_{t,n}$ is the price that intermediaries face, while it is $\mu_t p_{t,n}$ for consumers. The parameters for fish meal and

fish oil (FMFO) factories' demand are unknown; however, it is known that average commissioner prices, $p_{c,t,n}$, are around 7 times of average FMFO prices, $p_{f,t,n}$ (Table 4.8). Based on this limited information, FMFO demand is assumed to be more elastic than consumer demand and its elasticity parameter is set to $\vartheta_{fmfo} = -3$, with the following demand function:

$$p_{f,t,n} = B((1-\tau_t)Y_{t,n})^{\frac{1}{\vartheta_{fmfo}}} \tag{4.6}$$

where B is a constant that arranges the price ratio to reflect the current conditions. As a result, the total profit that fishing units acquire is:

$$\pi_{t,n} = \tau_{t,n}\left(p_{c,t,n}Y_{t,n} - c_{t,n}E_{t,n}\right) + \left(1-\tau_{t,n}\right)\left(p_{f,t,n}Y_{t,n} - c_{t,n}E_{t,n}\right) \tag{4.7}$$

where $c_{t,n} = \left(\tau_{t,n}p_{c,t,n} + \left(1-\tau_{t,n}\right)p_{f,t,n}\right)\alpha q E_{t,n}^{\alpha-1}X_{t,n}^{\beta}$ is the marginal cost of effort, acquired by the current profit maximization, $\frac{d\pi_{t,n}}{dE_{t,n}} = 0$.

It is also necessary to define the marginal cost function, which is equivalent to the inverse supply function. The marginal cost of the unit output is also determined by the profit maximization process, $\frac{d\pi_{t,n}}{dY_{t,n}} = 0$. Then, the marginal cost function is:

$$MC_{t,n} = \frac{\frac{c_{t,n}}{\alpha q X_{t,n}}}{\left(\frac{Y_{t,n}}{qX_{t,n}}\right)^{\left(\frac{1-\alpha}{\alpha}\right)}} \tag{4.8}$$

which is equivalent to the average price, $\overline{p_{t,n}} = \left(\tau_{t,n}p_{c,t,n} + \left(1-\tau_{t,n}\right)p_{f,t,n}\right)$. Then, the supply function becomes:

$$Y_{t,n} = qX_{t,n}\left(\frac{\left(\tau_{t,n}p_{c,t,n} + \left(1-\tau_{t,n}\right)p_{f,t,n}\right)\alpha q X_{t,n}}{c_{t,n}}\right)^{\left(\frac{\alpha}{1-\alpha}\right)} \tag{4.9}$$

Thus, the supply functions faced by the commissioners and FMFO factories are $\tau_{t,n}Y_{t,n}$ and $\left(1-\tau_{t,n}\right)Y_{t,n}$, respectively.

The state space, X_s, is acquired by initiating the stock level and effort levels at $\frac{K}{2}$ and $n^{\rho}E_{max}$, that determine its remaining $I-1$ values. Then, the elements of the state transition matrix are:

$$X_{i,j} = arg\ \underset{i}{min}\left|X_{s_i} - X_{i+1,j}\right| \tag{4.10}$$

where $X_{s_i}$is the i_{th} element of the state space, $X_{i+1,j}$ is the next stock level determined by E_{s_j}, which is the j_{th} element of the effort space. The index i in $X_{i,j}$ that represents the closest index in the state space is then assigned to the $I \times J$ state transition matrix at position (i,j). Then, the state transition function, f_{st}, and associated reward function, f_{rw}, can be defined as:

$$f_{st}\left(X_i, E_j\right) = X_i + G(X_i) - qE_i^{\alpha}X_j^{\beta} \tag{4.11}$$

$$f_{rw}\left(X_i, E_j\right) = \pi\left(X_i, E_j\right) \tag{4.12}$$

Finally, in the form of a Bellman equation, the value function can be constructed by the cumulative discounted profits of the fishing fleet:

$$V(E,X) = max_{E \in E_s}\{\pi(E,X) + \delta V(E,X)\} \tag{4.13}$$

where $\delta < 1$ is the discount factor.

Once the optimal initial effort levels are acquired for each season length, the stock and effort dynamics are allowed to reshape the future harvest levels, prices, costs, profits, and all components of social welfare, including consumer surplus, FMFO surplus, producer surpluses from the sales to intermediaries and FMFO factories, and intermediary profits.

As a result, the welfare effects of seasonal closures can be computed. For simplicity, 14 different season lengths with15-day intervals between 165 and 360 days of lengths. The social welfare in question has five components including consumer surplus ($CCS_{t,n}$), FMFO surplus ($FCS_{t,n}$), producer surpluses from the sales to commissioners ($CPS_{t,n}$) and FMFO factories ($FPS_{t,n}$), and commissioners' profits ($CPR_{t,n}$). They can be calculated as follows:

$$CCS_{t,n} = \int_{p_{c,t,n}}^{\infty} \mu_t^{\vartheta_1} p_{c,t,n}^{\vartheta_1} A_t \, dp_{c,t,n} \tag{4.14}$$

$$FCS_{t,n} = \int_{p_{f,t,n}}^{\infty} \frac{p_{f,t,n}^{\vartheta_{fmfo}}}{B^{\vartheta_{fmfo}}} dp_{f,t,n} \tag{4.15}$$

$$CPS_{t,n} = \int_{0}^{p_{c,t,n}} \tau_{t,n} q X_{t,n} \left(\frac{\left(\tau_{t,n} p_{c,t,n} + \left(1 - \tau_{t,n}\right) p_{f,t,n}\right) \alpha q X_{t,n}}{c_{t,n}} \right)^{\left(\frac{\alpha}{1-\alpha}\right)} dp_{c,t,n} \tag{4.16}$$

$$CPS_{t,n} = \int_{0}^{p_{c,t,n}} \tau_{t,n} q X_{t,n} \left(\frac{\left(\tau_{t,n} p_{c,t,n} + \left(1 - \tau_{t,n}\right) p_{f,t,n}\right) \alpha q X_{t,n}}{c_{t,n}} \right)^{\left(\frac{\alpha}{1-\alpha}\right)} dp_{c,t,n} \tag{4.17}$$

$$CPR_{t,n} = \left(\mu_t p_{c,t,n} - p_{c,t,n}\right) \tau_{t,n} Y_{t,n} \tag{4.18}$$

These values are calculated for $10T$ days. Thus, to evaluate the cumulative effect of each policy on these welfare components, their total discounted values are computed for each. To illustrate, the long-run cumulative consumer surplus for policy n is:

$$CCS_n = \sum_{t=1}^{10T} \delta^t CCS_{t,n} \tag{4.19}$$

Finally, the social welfare, W_n, for each policy is calculated by:

$$W_n = CCS_n + FCS_n + CPS_n + FPS_n + CPR_n \tag{4.20}$$

where CCS_n, FCS_n, CPS_n, FPS_n, and CPR_n are the present values of long-run cumulative values of the five welfare components.

4.4 Calibration

The parameters of harvest function, stock dynamics, and demand function have already been estimated in Chapter 2 and Chapter 3. Just as the discount factor, δ, since the estimate for intrinsic growth rate, $\hat{r} = 0.2893921$, is a monthly rate, it is discounted as $r = (1 + \hat{r})^{\frac{1}{30}} - 1$. Moreover, the coefficients of effort dynamics, $\gamma 1$ and $\gamma 2$, are externally estimated and discounted using the monthly effort levels and stock estimates in previous sections. On the other hand, the value of the parameter $\rho =$

-0.222 is simply a reasonable assumption that fishing units are willing to reduce their capacity utilization by 2.22% for each day added to the fishing season (Table 4.5).

Table 4.5 Model Parameters

Harvest Function	Catchability (q)	0.0000418
	Effort elasticity (α)	0.8786742
	Stock elasticity (β)	1.0000000
Stock dynamics	Intrinsic growth rate (r)	0.0085
	Carrying capacity (K)	1314970.0
Demand function	Price elasticity ($\vartheta 1$)	-0.814
	Income elasticity ($\vartheta 2$)	1.362
	Beef cross-price elasticity ($\vartheta 3$)	0.463
	Chicken cross-price elasticity ($\vartheta 4$)	0.450
	FMFO price elasticity (ϑ_{fmfo})	-3
	B	274.86
	Consumption share (τ)	0.575, 0.600, 0.625, 0.650, 0.675
Effort dynamics	γ_1	0.0010
	γ_2	-0.0092
	ρ	-0.222
Other	X_0	$K/2$
	E_{max}	1400, 2100, 2800, 3500
	E_0	$k^{\rho} E_{max}$
	δ	0.9996
	I_0	2160
	μ_0	2
	$p_{b,0}$	30
	$p_{c,0}$	6
	T	360

The daily fishing capacity is approximated by the data presented in Table 4.3, by assuming that fishing units work 24 hours a day, on average, during the fishing season. Since the average effort of the large-scale fisheries is around 600 GT-hours in the TurkStat Fisheries Micro Data Set, it is assumed that fishing units use 30% of their capacity, leaving significant room for increasing their capacity utilization. In order to address the capacity changes, possible capacity levels, and capacity reduction attempts, the models are replicated for the capacities of 2000, 3000, 4000, and 5000 GT-hours and the results are compared.

The value of consumption share, τ, is determined around the level estimated using the annual catch and sales data from the TurkStat Central Dissemination System

(MEDAS) to address recent regulation on the limitation of the anchovy sales to FMFO factories, which have remained above other sales since 2018 (Table 4.6). Accounting for the total sales, only 62.5% of the catch can be included in final demand (Table 4.7). By keeping others constant, the model is also replicated for the shares of 57.5%, 60%, 65% and 67.5%.

Table 4.6 Marine Catch Levels of Determined Seafood Groups (Tons)

Year	Anchovy (Consumer)	Anchovy (FMFO)	Sprat (FMFO)	Total
2014	59602	36838	41648	266078
2015	90886	102606	76996	397731
2016	55732	46864	50225	301464
2017	68212	35696	33950	267986
2018	60756	89882	20057	338141
2019	83031	179513	38078	431572
2020	59373	111880	26804	331281
2021	66483	85115	28041	295018
2022	45079	80902	11162	301747
Average	65461	85477	36329	325669

Source: TurkStat Central Dissemination System (MEDAS)

Table 4.7 Marine Consumer and Input Shares

Year	FMFO	Consumer
2014	0.295	0.705
2015	0.452	0.548
2016	0.322	0.678
2017	0.260	0.740
2018	0.325	0.675
2019	0.504	0.496
2020	0.419	0.581
2021	0.384	0.616
2022	0.305	0.695
Av.	0.374	0.626

Source: TurkStat Central Dissemination System (MEDAS)

Finally, the ratio of consumer prices to input prices is determined according to the same data set. As illustrated in Table 4.7, the average anchovy prices for consumers between 2014 and 2018 is 7.597, while it is 1.828 for FMFO factories. Accounting for other species, the ratio of consumer prices to input prices increases to around 7.

Table 4.8 Average Prices (TL)

Year	Anchovy (Commissioner)	Anchovy (FMFO)	Sprat (FMFO)	Total
2014	3.290	0.770	0.610	3.806
2015	3.670	0.760	0.580	2.955
2016	4.290	1.100	0.620	4.060
2017	5.960	0.960	0.640	5.058
2018	5.770	1.130	0.790	5.274
2019	7.310	1.440	0.950	5.108
2020	10.220	1.920	1.030	8.031
2021	12.490	2.700	1.520	11.451
2022	20.100	5.060	2.040	21.662
Average	7.597	1.828	0.820	7.278
Average (Commissioner)	10.713			
Average (FMFO)	1.527			

Source: TurkStat Central Dissemination System (MEDAS)

4.5 Results

Before obtaining several results about stock, effort and market dynamics under various seasonal closure and FMFO share policies, it is essential to set a maximum sustainable yield rule in order to avoid complexities. The stock and effort dynamics are used to obtain the steady-state stock-effort combination that produce the maximum sustainable yield. As a result, the optimal daily effort level, $E^* = 192.479$, the yield, $Y^* = 2797.06$, where the steady-state stock level is $X^* = 657107$ tons (Figure 4.1). Thus, any deviation from this stock level leads to lower outputs and one of the aims of the fisheries policy is to keep the stock levels as close as to this.

Although this study cannot respond the question of when to fish, by computing and comparing the average stock levels for different policy combinations, it may answer the one regarding how long to fish. Figure 4.2 illustrates that the dynamic stock levels in Turkish territorial waters are lower than X^* under current seasonal closure policy and other conditions. Not surprisingly, longer season lengths result in even larger deviations from MSY, making it obvious that, under all other similar conditions, the season length must be decreased.

Figure 4.1 Maximum Sustainable Yield, Effort and Stock

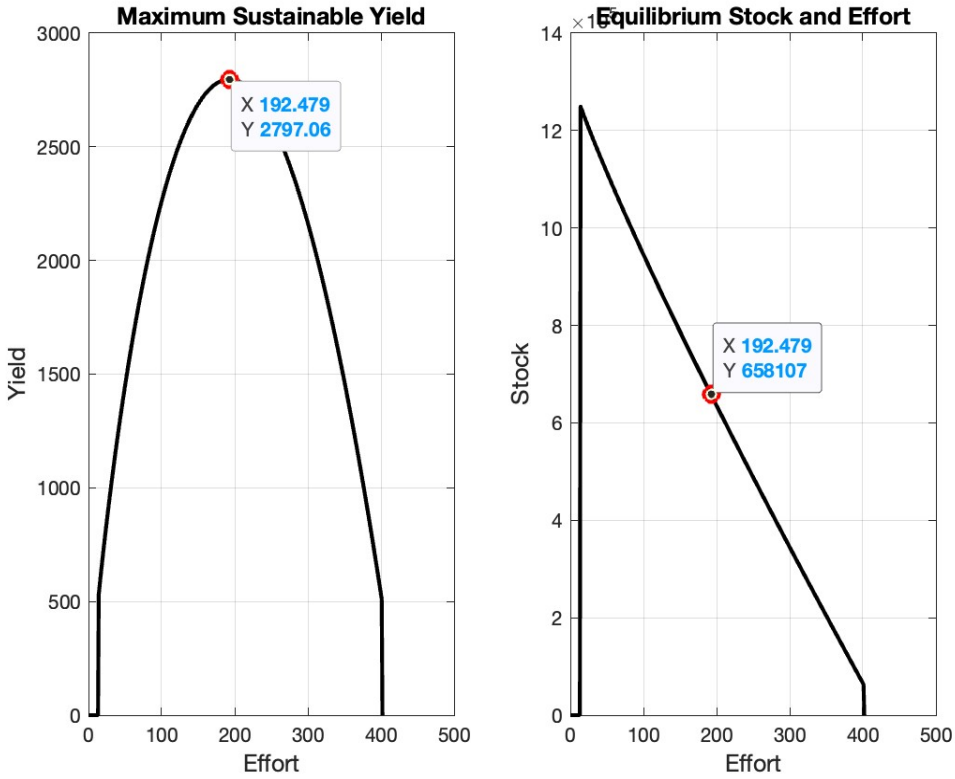


Figure 4.2 Stock Dynamics for Different Season Lengths

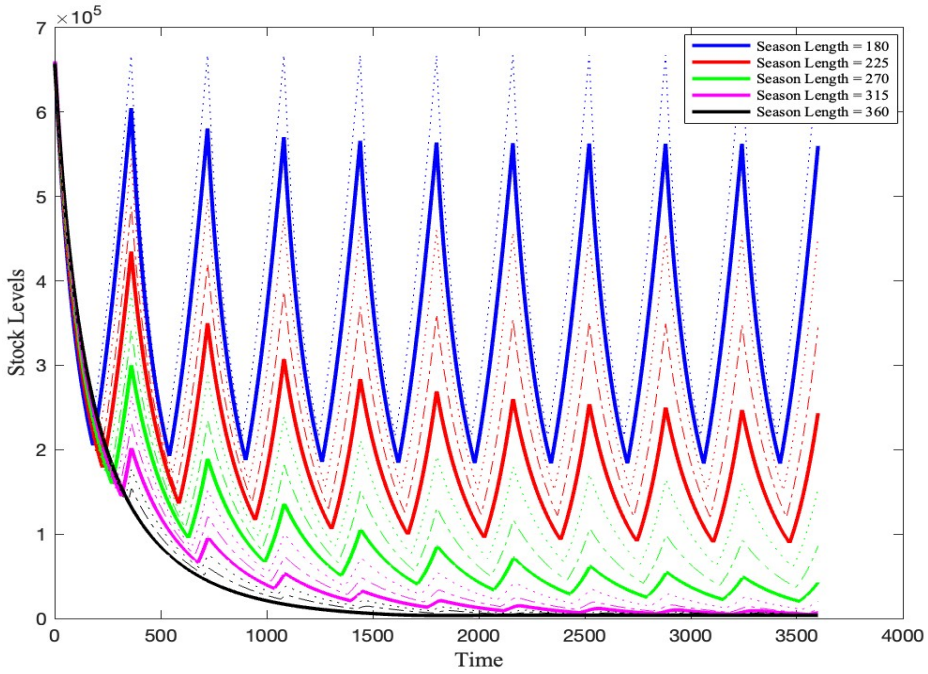
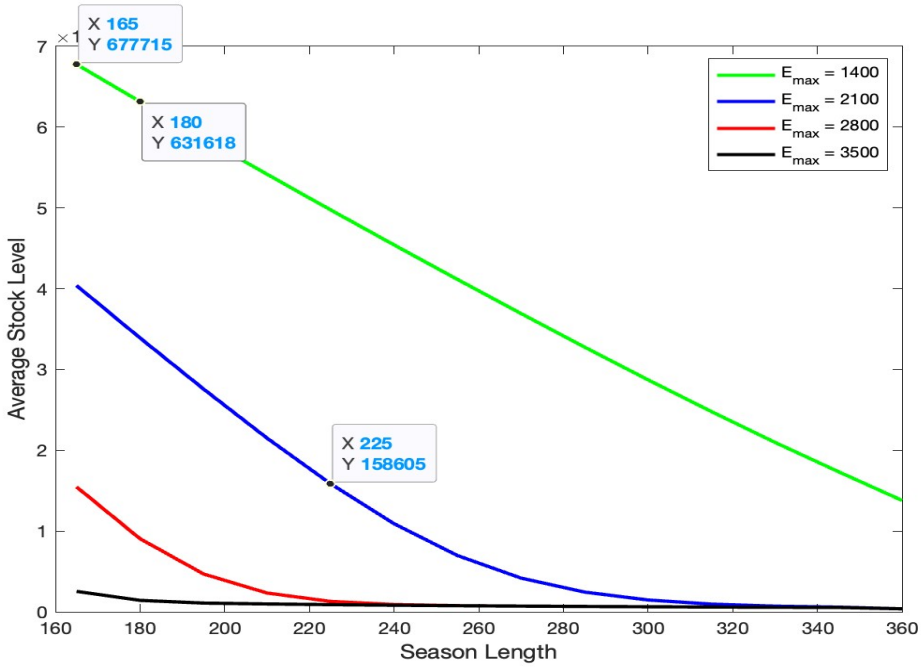


Figure 4.3 illustrates the 10-year long-run averages of the stocks for scenarios for fisheries. In the current policy where season length is 225 days and fishing capacity is 2100 GT-hours, the predicted average stock level is 158605 tons, much lower than the

MSY level. In addition, Even the season length is shortened by 2 months, it remains much below the desired level. Although there can be many alternative policy combinations, among the scenarios evaluated in this study, the only detected scenario to attain MSY is to reduce the fishing capacity to 1400 GT-hours along with a reduction in the season length by around 1.5-2 months. In fact, capacity increases might even worsen the stock levels.

Figure 4.3 Average Stock Levels



To be more illustrative, Figure 4.4 demonstrates that although the effort levels can be reduced below 300 GT-hours depending on the stock levels, the current capacity, $E_{max} = 2100$, and associated maximum effort level of 631 GT-hours leads to a reduction in the stock levels down to 90481 tons. When $SL = 225$, the 135 days of seasonal closures can recover the stock levels to at most 349497 tons. As the current effort level is determined by a linear combination of current stock and previous effort, it occasionally falls below 631 GT-hours. In other words, fishing units do not perform their maximum effort until stock do not recover to a desirable level.

According to our model, a sole reduction in the season length by 2 months with the existing capacity of $E_{max} = 2100$ increases this range to 217410-667660 tons with a constant effort level of around 676 GT-hours. Similarly, a sole reduction in the fishing capacity to $E_{max} = 1400$ with the current season length of $SL = 225$ increases it to 349779-696888 tons with a lower constant effort level. In the scenario where the

maximum average stock level is obtained; in other words, the fishing capacity is $E_{max} = 1400$ and the season length is $SL = 165$, the effort level during the season is constant at 450.657 GT-hours.

Figure 4.4 Phase Diagrams with Seasonal Closures

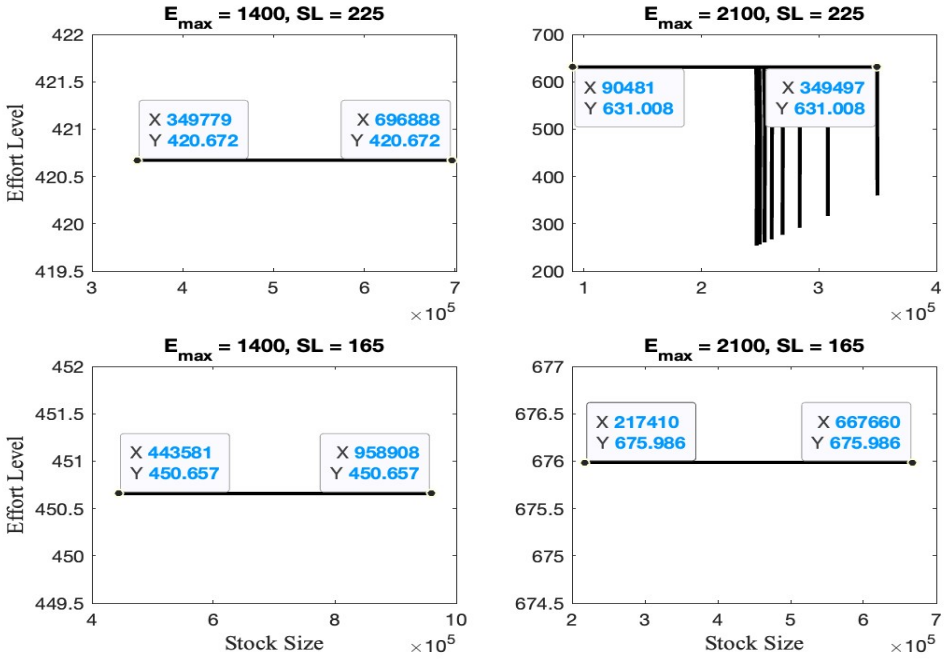
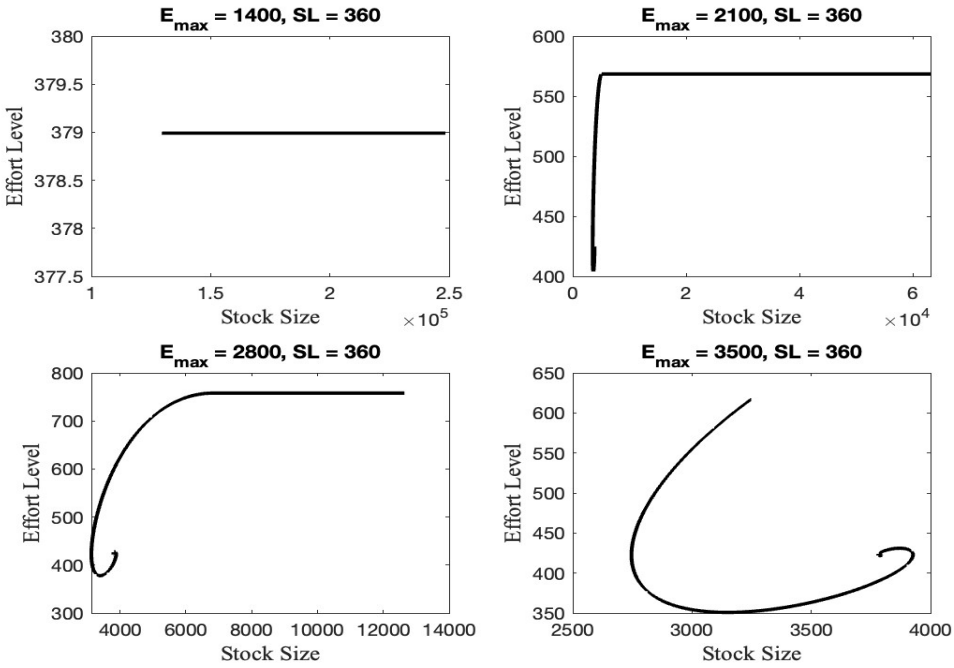


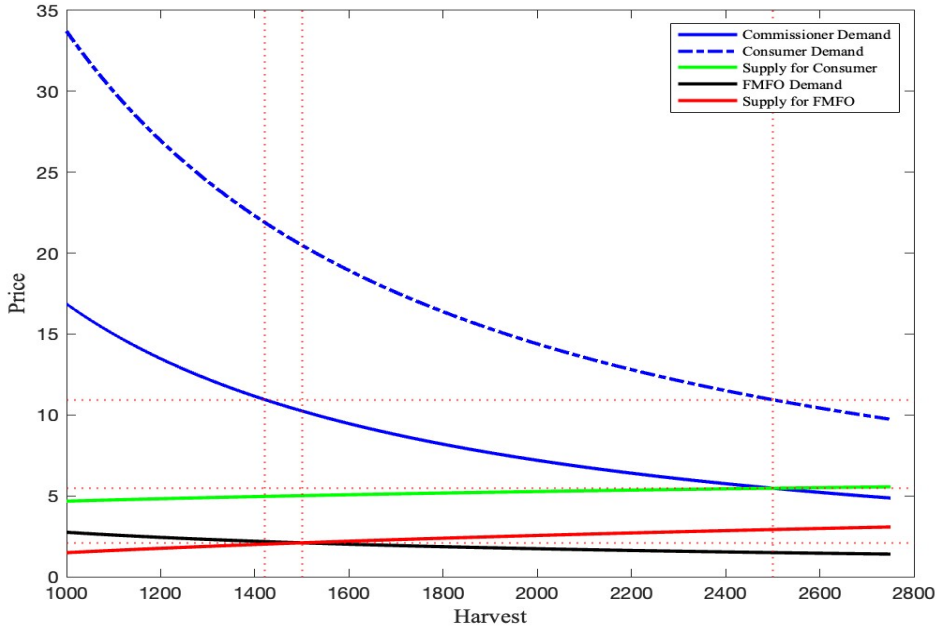
Figure 4.5 Phase Diagrams without Seasonal Closures



Thus, for a more effective season length policy that should be between 165 and 180 days, either the fishing capacity should be reduced by one-third of the current level or

the measures that set the daily average effort to below 450.657 GT-hours. Annually, it can be calculated as 74358.405 GT-hours, regardless of the season length policy. Figure 4.5 illustrates the scenarios when there are no season length restrictions. If the fishing capacity is very large at $E_{max} = 3500$, the current effort levels the stock levels are eliminated down to below 4000 tons with lower capacity utilization and low harvest levels. As the capacity is gradually reduced, they lead to relatively larger equilibrium stock levels. Still, in the absence of season length policies, resulting equilibrium stock levels will be much smaller in the long term, regardless of the fishing capacity. Overall, a fisheries policy to preserve the stock levels must be based on a stricter season length policy and controlling the fishing effort.

Figure 4.6 Inverse Supply and Demand



Unfortunately, such actions might lead to serious oppositions from the stakeholders, mostly including fishing communities and FMFO factories. Thus, it is essential to evaluate the welfare effects of these policies. To begin with, it is necessary to explain the current market conditions. Figure 4.6 illustrates the supply and demand functions of the related agents when the fishing capacity is 3500 GT-hours, season length is 225 days, allowed FMFO share in the market is 37.5%, and it is the 90th day of the first season. The blue and green lines illustrate the market for the commissioners. They purchase the associated output from the fishing units and sell them to the consumers with demand function illustrated by the blue dashed line. In this market, the consumer surplus, commissioner profit, and producer surplus from commissioner sales are

determined. If there were no commissioners in the market, consumers would like to purchase more seafood from the fishing units with cheaper prices and fishing units could sell them with higher prices. As a result, share of FMFO factories would fall without any policy intervention. It is clear that commissioner power in the market leads to a welfare loss.

Figure 4.7 Consumer Surplus

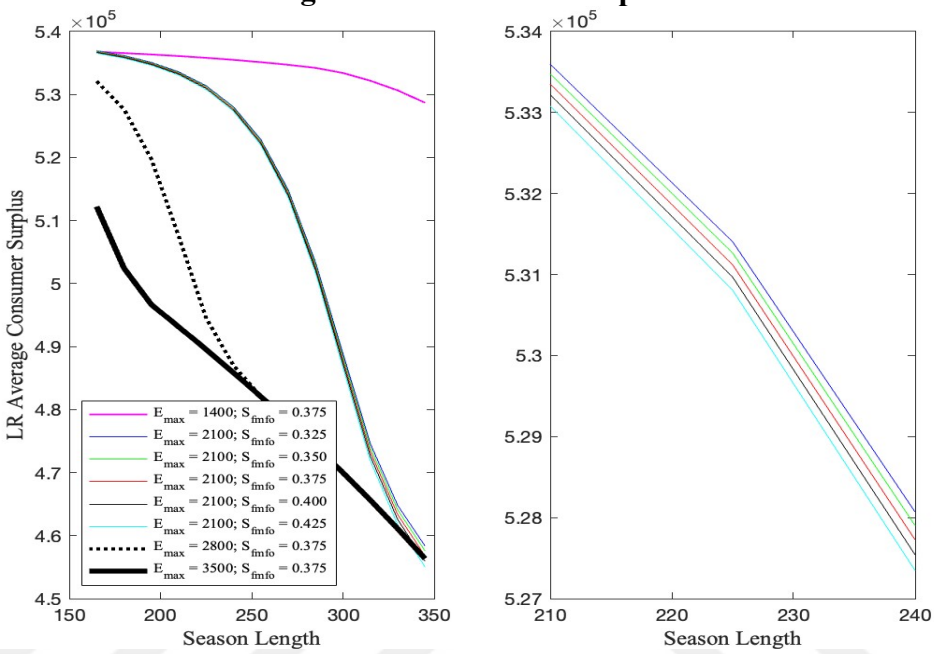


Figure 4.8 FMFO Surplus

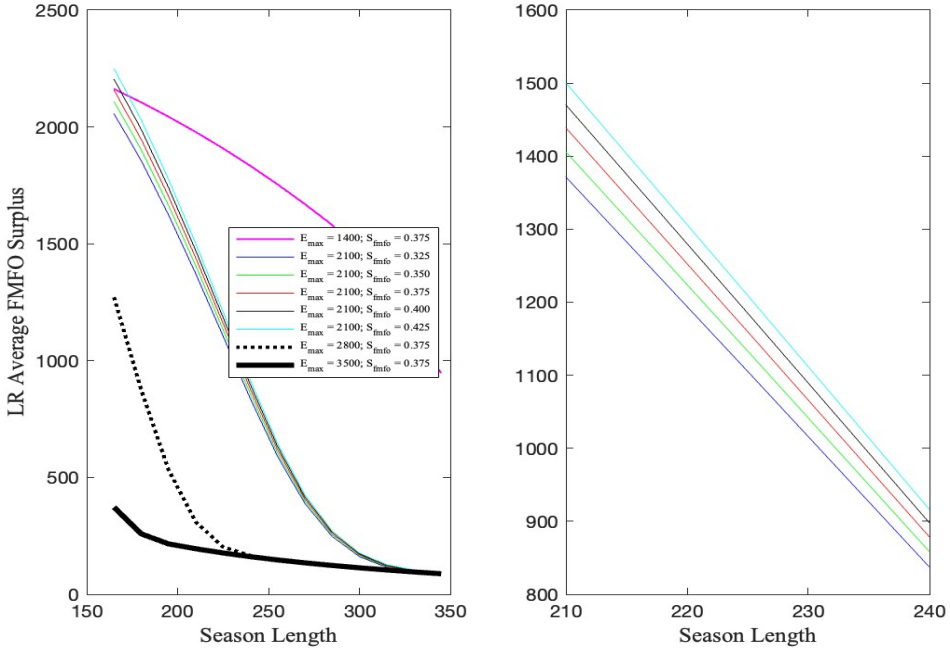


Figure 4.7 illustrates the consumer surplus from under different policies. A reduction in the season length increases consumer surplus regardless of the capacity or the FMFO share in the market. Moreover, capacity reduction and reduced FMFO shares

increase the consumer welfare. Similar policy impacts are observed in the FMFO surplus except that they require more share in the market (Figure 4.8).

Figure 4.9 Producer Surplus from Commissioner Sales

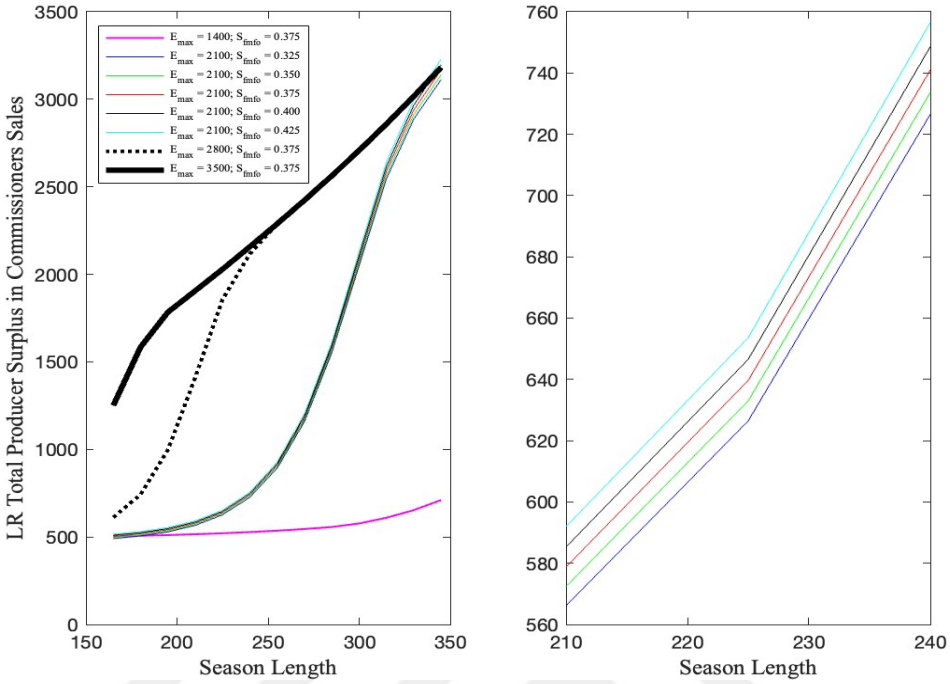


Figure 4.10 Producer Surplus from FMFO Sales

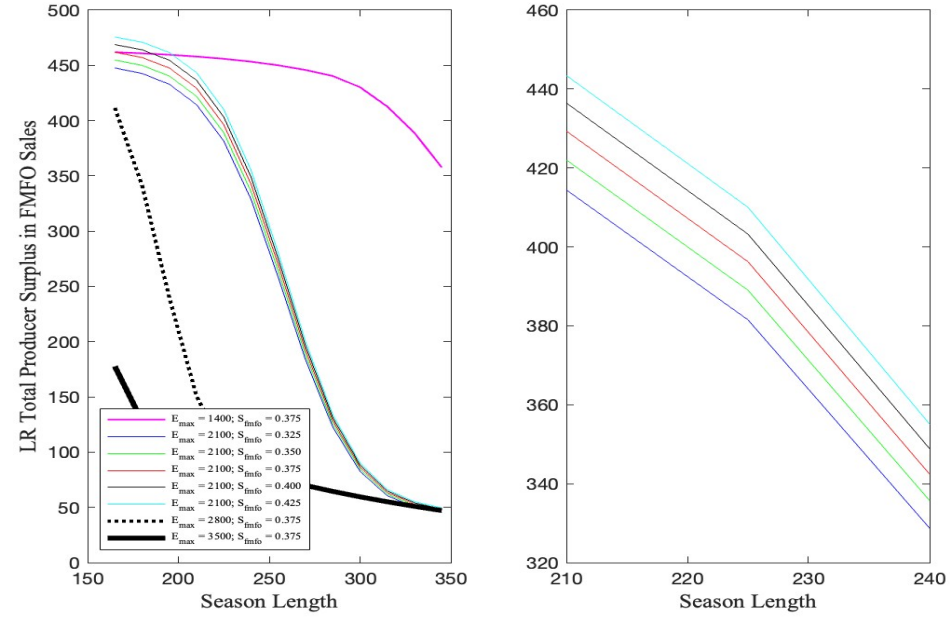


Figure 4.9 and Figure 4.10 illustrate the producer surplus from the two markets. Capacity reductions and season length restrictions reduce the welfare of the fishing units in the commissioner market although a relatively lower welfare gains is found in the FMFO sales. In both markets, fishing units face a welfare loss from the FMFO

share reductions. Commissioners also face welfare losses from the policies that favor consumers (Figure 4.11).

Figure 4.11 FMFO Surplus

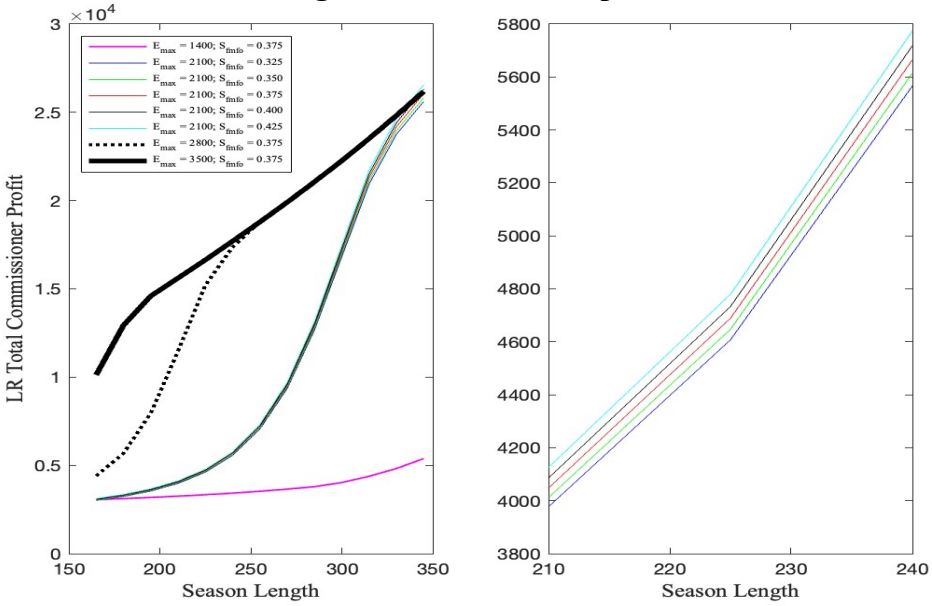
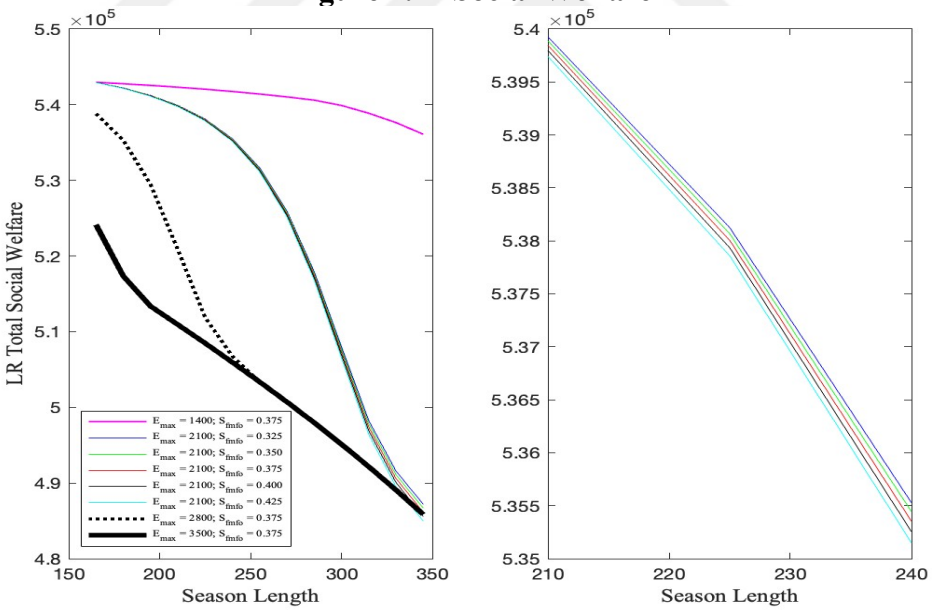


Figure 4.12 Social Welfare

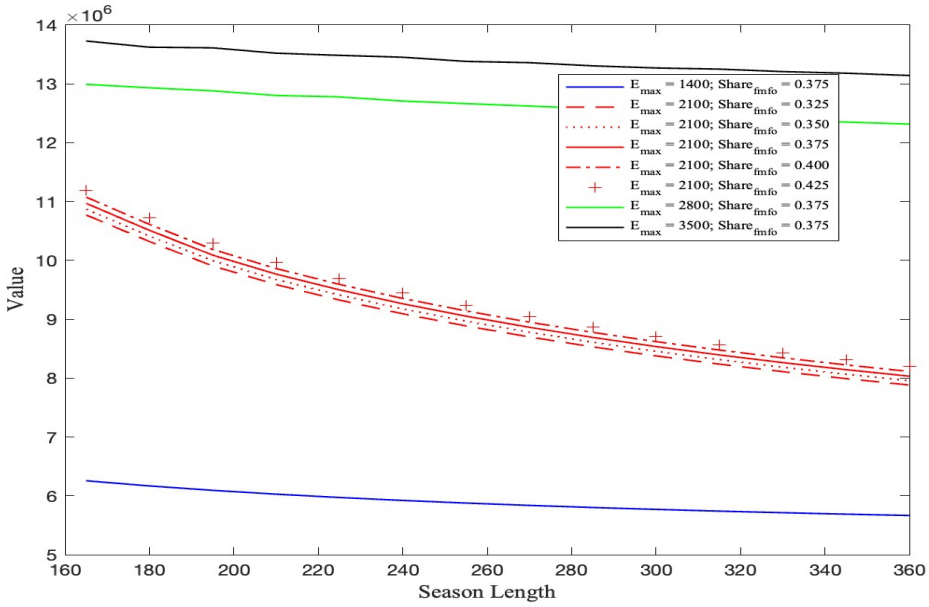


Overall, since consumer surplus is by far the most dominant component of the total social welfare, society benefits from the capacity reduction, longer seasonal fishing bans, and lower FMFO shares in the market (Figure 4.12). Moreover, although not directly stated, both consumers and fishing units benefit from the reductions in the intermediary power in the market. Fortunately, the considerations for natural resource conservation and total social welfare do not contradict each other in the requirement for the necessary policies; however, political pressures from fishing communities,

FMFO factories that are essential for aquaculture production, and commissioners, who face welfare losses from these policies should be considered.

Finally, it is worth comparing the sum of discounted fishing unit profits that is maximized under each policy as most studies in the literature ignore the welfare effects and consider this in their analyses (Figure 4.13). Similar to the producer surplus, fishing unit profits are reduced by all three policies. However, ignoring the social welfare and environmental considerations by only taking this value into account might lead to misleading policy implications in the literature.

Figure 4.13 Value



4.6 Discussion

The application and results of this study have important implications for both literature and fisheries management policies. First, it illustrates that ignoring other welfare effects and focusing either solely on rent maximization or natural resource conservation in bioeconomic modelling lead to unilateral policy suggestions despite multifaceted nature of the fisheries management policy. Although profit maximization process is essential in most microeconomic studies, the welfare effects it result in must be the primary tools of the policy making. Moreover, the conclusions that are obtained for only on resource conservation overlook the political realities of the real world. As Wilen & Homans (1998) have pointed out, an effective fisheries management system must affiliate with both scientific data and political realities. Thus, as suggested by

Jensen et al. (2019), accounting for consumer surplus and producer surplus allows the fisheries regulator for choosing better policy arrangements.

Secondly, the results regarding the biomass levels in Turkey are in alignment with the ones in Demirel et al. (2020), promoting large reductions in the fishing pressure to get closer to the MSY level. More specifically, this study suggests around 33% of capacity reduction along with 2 months increase in the seasonal fishing ban. Thus, the necessary season length policy is even larger than the suggestion for the Marmara Sea in Demirel et al. (2023). An alternative to these policies would be effort reduction policies that diminish capacity utilization instead of the total fishing capacity and season length.

Nevertheless, neither capacity and effort reductions nor season length limitations are easily applicable policies. The failures of previous buyback and the current fleet composition (Table 2.2 and Table 4.3) illustrate that it is hardly possible to diminish the fishing capacity. In fact, increased use of fishing technologies, stable efficiency levels despite declining stocks, and vessel compositions favoring larger tonnage levels with the stable number of vessels illustrate that fishing power tends to grow. Capital non-malleability in fisheries defined as the limitations on divestment (Clark et al., 1979) due to capital stuffing (Dupont,1990) is a problem that can only be solved by a wholistic management policies including sectoral and multi-species level decisions rather than the ones on individual fisheries (Rust et al., 2016). In other words, the management must discourage the fishing units to invest by imposing stricter regulations covering all.

As mentioned before, the most significant policy measure that covers all large-scale fisheries is the existing season length restriction. Although the model in this study does not present an association between fishing capacity and season length, longer-term unemployment might lead to exits from the fisheries as fisher welfare and profitability are reduced (Figure 4.9 and Figure 4.13). However, the example presented in Wilen & Homans (1998) and the fact that the last decrease in the season length in Turkey has been introduced as only 15 days for almost a decade ago, this policy can probably be applied gradually covering several circular periods unless the fisheries policy is comprehensive and aggressive. Luckily, the policies that favor environmental conservation result in significant welfare gains, mostly driven by consumer surplus. The problem is that fishers and commissioners that face welfare losses and it is highly

possible that those policies would face strong oppositions from these agents, slowing down the implementation of the policies.

Even though the limitations on the market share of the FMFO factories have no effect on the stock and effort levels in the model, their market effects are worth considering in association with the intermediary profits. The problem with these agents is that they have great power in the prices, reducing the welfare of both consumers and producers. Since the only species that is demanded by both FMFO factories and consumer is anchovy, it is a positive development that the relevant regulation is recently introduced for it (TOB, n.d.). However, even a stronger policy would limit the intermediaries that would lead to higher quantity demanded for all wildly captured seafood with lower consumer but higher producer prices and automatically reduced market share of FMFO factories. Thus, as pointed out in (Yildiz et al., 2023), market channels that fishing units can directly sell to consumers should be supported and promoted to reduce the market power of both FMFO factories and middlemen. These channels include stronger cooperative structures and online fish markets strengthened by cold logistic chains that can directly meet fishers and consumers.

4.7 Conclusion

The conclusions of this study have substantial significance for fisheries management strategies and economic literature. It emphasizes that a sole emphasis on rent maximization or resource conservation results in one-sided policy recommendations, disregarding wider welfare implications. While profit maximization is essential in microeconomics, policy choices must focus the effects on general wellbeing. Effective fisheries management necessitates the integration of scientific data and political reality. The findings on biomass levels in Turkey indicate a 33% decrease in fishing capacity and a two-month extension of the seasonal fishing ban to attain MSY. Alternatively, regulations aimed at reducing effort may diminish capacity usage instead of explicitly constraining capacity and the duration of the season. Both options encounter practical difficulties with historical and observational realities.

Capital non-malleability due to capital stuffing worsens divestment challenges, requiring comprehensive management strategies at both sectoral and multi-species levels. The main regulation comprehensively applies large-scale fisheries in Turkey is the limitation of fishing seasons. The study did not demonstrate a clear correlation

between fishing capacity and season duration; nonetheless, extended unemployment periods and reduced profit opportunities may compel fishermen to leave the sector. However, it is recommended that policy implementation be gradual to alleviate resistance from impacted groups.

Policies promoting environmental protection enhance consumer surplus but encounter opposition from fishers and commissioners suffering welfare losses. FMFO factories and intermediaries exercise considerable influence on pricing, diminishing the welfare of both consumers and producers. Although new laws focus on anchovy, supreme policies should curtail the impact of the middlemen, covering all species. Enhancing direct market channels, like cooperatives and online fish marketplaces, would mitigate their influence and augment fisher profits.

Although this study proposes significant insights for both fisheries policy and resource management economics, it can be developed in several ways through future research. To begin with, as an aggregated study, the analysis neglects species-specific dynamics and migration behaviors of biological populations. There are many fluctuations in the monthly predicted stock levels that cannot be explained by a simple logistic growth function and market prices of various species differ with their specific characteristics. Besides, FMFO factories create value and provide inputs for the aquaculture facilities that produce seafood, and they compete with the captured ones in the market. A better model would include the production functions of FMFO factories and aquaculture facilities that are also profit maximizers. Additionally, there are inland water fisheries that also interact with marine captured and cultured products. Finally, foreign trade is an important aspect of the seafood markets for both intermediate and final goods. Although FMFO factories in Turkey provide substantial inputs for aquafeed industry, even larger amounts are imported, while an important portion of the cultured seafood is exported (Table 3.3).

5 CONCLUSION

To formulate more effective policies for achieving efficient, optimal, and sustainable fisheries in Turkey, and to mitigate the adverse effects of overfishing, it is essential to analyze catch, consumption, and their interactions. This dissertation presents a bioeconomic modeling of Turkish fisheries that is based on the empirical evidence on fleet characteristics, catch, consumer behavior, demand, and the current status of national fisheries policy. As the number of dimensions in such an analysis can be very large, it is extremely challenging to consider all in a unified model. Thus, each essay that gradually builds the model has determined several priorities and made necessary simplifications to obtain expressive results.

To begin with, among the challenges that world fisheries face, this dissertation argues that the most important one in Turkey is overfishing. Especially after the transition to market economy and strong government support for industrial practices during 1980s, Turkish fisheries had quickly attained its historical peak by the end of the decade, followed by a gradually declining trend since then, leading to diminishing benefits. However, the initial necessary measures have been taken only after the end of 2000s. Still, even the most recent studies emphasize the necessity of much stronger input controls.

Secondly, it is empirically observed that seafood consumption is lower in Turkey compared to world averages and other sources of animal protein despite its long coastline, abundant inland water resources, and expansions in aquaculture. Although total seafood production is high in Turkey, the first reason is that the domestic supply of consumption goods is low due to high market shares of FMFO factories and exports. Secondly, there may be some economic and demographic characteristics leading to low demand.

Finally, it is necessary to define the status, nature, challenges in Turkish fisheries regime. Being directly related to the resource conservation and overfishing problems, the success of season length restrictions and capacity reduction efforts are the most important elements of the fisheries management actions in Turkey. Secondly,

associated with the low consumption and profit levels, the effects of the recent limitation on the FMFO share in the market and market power of the commissioners need to be considered.

The knowledge of low stock status and high fishing capacity in Turkey unambiguously indicates that overfishing is the primary issue. The essay in Chapter 2 first presents estimates of stock levels along with the parameters of stock dynamics. To do so, a two-step generalized fishery model is estimated by making use of the panel data obtained from the TurkStat Fisheries Micro Data Set (2015-2021). In the first step, stock indexes for 56 months are obtained by considering harvest as a function of the defined effort and a set of dummy variables constructed by the regional, technical, and technological characteristics of the vessels. Then, the obtained stock indexes and harvest levels are utilized to estimate the logistic growth function with the parameters of catchability, intrinsic growth rate, and carrying capacity. Finally, the stock estimates are obtained by the stock indexes and estimated catchability.

Although the 7-year trend in stock levels seems stable, it is found that Turkish fisheries suffer from being below MSY levels. In other words, the historical overfishing is shown in the diminished ratio of average monthly stock to carrying capacity, hindering fisheries from attaining the maximum sustainable yield (MSY). The results also indicate that the more stable fishing effort alone does not account for harvest changes; rather, they are predominantly influenced by the fluctuations in the stock levels. Furthermore, regional variety in the results indicates that fisheries programs must be customized to the specific stock circumstances of each location. The Levantine Sea demonstrates the most stable fisheries due to its warmer climate and low biomass, whereas the Aegean Sea has challenges of territorial conflicts and marine farming. The Western Black Sea has seen stock recovery and efficiency improvements; however, the Eastern Black Sea and Marmara regions are troubling, with a decline in technical efficiency despite higher output levels.

Next, these stock estimates are incorporated into a panel stochastic frontier model with inefficiency effects. The frontier model is constructed as a Cobb-Douglas harvest function and the factors of inefficiency include the regional, technical, and technological characteristics of the vessels. It is found that there is significant room for efficiency gains in Turkish fisheries that have a potential for deepening overcapacity problem and signal the necessity of stricter regulations. Moreover, some

fishing methods that are environmentally damaging are found to be less efficient than others while the use of fish-finding devices enhances efficiency.

The significance of this research lies in its utilization of the available micro data set to estimate the bioeconomic parameters, stock levels, and harvest function with recent characteristics of Turkish fisheries. Moreover, these parameters contribute to a more reliable modeling in Chapter 4. Furthermore, this research combines bioeconomic parameter estimates with inefficiency analysis to examine technical efficiency in fisheries. In contrast to other studies, it recognizes the influence of stock variations on productivity and the inefficiencies in catch operations.

The regionally decomposed investigation underscores the requirement for tailored strategies that include ecological, political, and economic factors. More stringent regulations must be implemented in the regions confronting substantial stock depletion. Environmental enhancements in the Marmara Sea necessitate waste management and maritime traffic rules, as well as a more reduced fishing season, to assist faster stock recovery. In the Eastern Black Sea, an implementation of Individual Transferable Quotas (ITQs) for economically significant species may stabilize catch variability and aid in the restoration of essential populations such as anchovies. Fortunately, there is a recent regulation stepping towards this policy. Mitigating the harmful impacts of ecologically damaging fishing equipment and fisheries-related technical externalities are also essential across all fishing regions.

Chapter 3 provides unique comprehensive research on Turkish seafood demand, employing a multi-stage budgeting methodology and correcting for sample selection bias to overcome the low seafood share in household budgets and zero consumption shares. A synthesis of methodologies for addressing censored dependent variables and demographic scaling is employed, building upon prior research. A five-stage decision tree from income to three significant seafood categories is utilized.

A significant conclusion is that total household expenditures exhibit more sensitivity to price levels than to income, indicating that wealthier families are inclined to save rather than increase their expenditures. However, food expenditures are found more responsive to overall spending than to fluctuations in price or income. Seafood, red meat, and chicken have varying elasticity patterns among dietary categories, with seafood and red meat categorized as luxuries, whilst poultry is seen as a necessity. Anchovies and aquaculture-produced seafood are found to be luxury goods, whereas

other seafood is considered inferior. The higher price elasticity of seafood indicates that Turkish families exhibit significant sensitivity to price variations, resulting in less stable seafood consumption compared to other protein sources.

Moreover, larger households and those with higher disposable income dedicate a more significant portion of their budget to seafood, though the effect differs. Wealthier households living in better residences are more inclined to consume seafood, whereas those in inadequate housing and facing financial difficulties exhibit reduced sensitivity to fluctuations in price and income. Moreover, there is a strong association between seafood consumption and expenditures on restaurant, tobacco, and alcohol.

The study explains both structural and cultural barriers to seafood intake in Turkey. The interaction of restricted local seafood supply, raised costs, and cultural attitudes enhances its reputation as a luxury item. Government subsidies for aquaculture might enhance accessibility; nevertheless, sustainability issues, like diminishing anchovy populations and escalating feed expenses, must be resolved. Anchovy, a fundamental component of Turkish cuisine, is predominantly utilized in aquaculture feed instead of being directly accessible for consumption; hence, diminishing its affordability. Moreover, increased seafood exports lead domestic consumers to compete with foreigners, limiting local availability.

Two principal measures are recommended to enhance seafood intake. First, the availability of domestic seafood must be improved. Policies should prioritize enhancing the accessibility of anchovies for household consumption instead of reallocating them for fish meal and oil production. Recently imposed limitations on the sale of anchovies to FMFO producers may provide a redirection of supply to consumers. Moreover, initiatives should be undertaken to enhance the sale of aquaculture fish in local markets at more competitive rates, regardless of their requirement for imported feed. Providing subsidies and incentives to fish vendors would further advance this objective. Exporting aquaculture items that are incompatible with Turkish cuisine, while emphasizing the local sale of culturally appropriate species, might improve availability.

Secondly, seafood must be repositioned as a necessity rather than a luxury. Currently, seafood consumption is predominantly found in coastal areas characterized by marine tourism and historical ties to affluent demographics. Most seafood, captured or cultured, is directed towards upscale restaurants or exports, so constraining regular

consumption for the typical Turkish home. Besides, inland areas have a weak seafood consumption culture despite the recent developments in inland aquaculture.

Public campaigns should highlight the significance of seafood, while simultaneously instructing homes on conservation and culinary methods. Government policies must incorporate subsidies and financial assistance programs to enhance the affordability of fish for low-income individuals and larger families. Enhancing logistical networks and cultivating relationships with local fishers and aquaculture producers would provide a more equitable distribution of seafood throughout Turkey.

Lastly, Chapter 4 proposes a bioeconomic model of Turkish fisheries, grounded in empirical evidence from prior research and supported by plausible values derived from annual data sets. This study recognizes large-scale fishing units, which constitute the predominant portion of the catch, as the fishing fleet regulated by an authority. The management has several possibilities for fishing restriction policies; each aimed at regulating total annual effort at different levels and determining the duration for stock recovery. Furthermore, management can determine the percentage of seafood sales designated for FMFO facilities. In a deterministic discrete-time, discrete-state model, fishing units evaluate their initial conditions to maximize their cumulative discounted earnings. This paper provides a model with an infinite horizon, given that fishing resources are renewable.

The study highlights the impact of FMFO enterprises and intermediaries on market dynamics. While FMFO market restrictions may not directly influence stock and effort levels, they significantly affect pricing, hence reducing both consumer and producer welfare. Anchovy is the only species pursued by both FMFO firms and consumers, making the existing regulatory measures sound. However, stricter regulations limiting middlemen power on prices may improve market efficiency. The study recommends the support of direct market channels, such as cooperatives and online seafood marketplaces, to reduce the market power of middlemen and FMFO producers. ‘

The findings advocate for a 33% reduction in fishing capacity and a two-month extension of the seasonal fishing moratorium to attain MSY. However, implementing these measures is challenging. Despite declining stock levels, innovations in fishing technology and stable efficiency levels indicate an increase in fishing power, driven by vessels with enhanced capacity. The problem is that once an investment is made on fishing activities for its specific purpose, it is harder to convert into a financial asset.

Thus, the investors of fisheries have stronger incentives to stay in the market. Thus, it is essential to establish comprehensive management strategies that cover national fisheries, rather than regulating individual fisheries. In fact, more stringent regulations should be implemented to discourage investment in enhanced fishing capacity.

The primary regulatory mechanism governing Turkish large-scale fisheries is the restriction on the length of the fishing season. However, the last limitation on Turkey's fishing season was just 15 days, implemented around a decade ago, indicating that the adjustment to the desired policy might take a long time. Policies that advocate for environmental conservation increase consumer surplus but may face considerable opposition from fishers and commissioners experiencing welfare losses, hence hindering implementation.

This study has significant implications for fisheries management and economic literature, demonstrating that a sole focus on rent maximization or resource conservation leads to one-dimensional policy suggestions. Effective fisheries management must integrate scientific evidence with political realities, since disregarding welfare consequences results in limited policy perspectives. While profit maximization is a core principle of microeconomics, policy decisions must prioritize broader welfare considerations.

To conclude, this dissertation makes significant contribution on fisheries management, disaggregated demand analysis and bioeconomic analysis of Turkish fisheries by first estimating the bioeconomic parameters, determinants of technical inefficiency, and seafood demand, then constructing a dynamic model reflecting Turkish seafood market and fisheries policies. Along with the diverse implications that studies yield, they also have a few limitations but informs for several opportunities for future research. To begin with, the study in Chapter 2 is an aggregate analysis covering only large-scale fisheries. It can be replicated for specific species, gear types and regions and extended to small-scale operations. Secondly, Chapter 3 employs an old data set due to the methodological choice. Relatively new data sets may be used with alternative methodologies that suit them.

Lastly, the future research prospects for Chapter 4 are more extensive than the prior ones. First, its approach overlooks species-specific dynamics and migratory patterns of biological populations. The market values for different species vary according to their distinct traits and monthly estimated stock levels exhibit many variations that

cannot be revealed by a basic logistic growth model. Besides, FMFO factories provide value and supply inputs for aquaculture facilities that cultivate seafood. An improved model would incorporate the production operations of FMFO manufacturers and aquaculture facilities that are also subject to profit maximization. International trade is also a crucial component of the seafood markets for both intermediate and final products. Despite the significant contributions of FMFO manufacturers in Turkey to the aquafeed sector, even greater quantities are imported, while a considerable share of the cultivated seafood is exported. Finally, inland water fisheries engage with both marine-captured and cultivated goods.

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