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# Input Use and Incentives in the Caribbean Shrimp Fishery: The Case of the Trinidad and Tobago Fleet

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**Abstract** *This paper examines the economic factors that influence output in the Trinidad and Tobago shrimp fishery using a Generalized Leontief production function. Factors such as output prices and the use of inputs in the fishery are assessed. The artisanal and industrial fleets operate in a largely open-access fishery, which is seasonal. While shrimp is the main targeted species, various fish species are also targeted using gear modifications. It was found that for the artisanal shrimp trawl fleet in Trinidad and Tobago, effort, in terms of trip days, was estimated to have a significant effect on both shrimp and bycatch landings at almost similar levels. The relative price of the two species was not found to be significant, and no annual trends in the production of either was observed. However, the high season for shrimp landings, January to June, was found to have significant inverse effects on shrimp and bycatch landings.*

**Key words** Generalized Leontief production function, effort, shrimp, Trinidad and Tobago.

JEL Classification Codes Q21, Q22, C33.

## Introduction

Globally, fish and other seafood products continue to be a major source of protein, and the demand for these products has risen over time as the world's population increases and people express preferences for alternative sources of protein that are perceived as being more healthy. In many parts of the world, fish also provides a significant source of employment, income, and food security. This is particularly so in developing countries, where per-capita incomes are low and growth rates of the national economies are low or even negative. Even as these economies turn to new sectors for economic growth, the fisheries sector maintains its importance because of the increasing demand for fish. Further, these resources are often exported as a source of much needed foreign exchange.

With increasing income and population growth rates in developing countries relative to developed countries, it is expected that global fish consumption will rise (Delgado and Courbois 1998). Further, the fisheries sector usually supports whole communities, from the input suppliers to the fish vendors and processors. In addition, many developing countries also now view their fish stocks as under-exploited natural resources, which can be more intensively explored to meet the growing global and local demand for fish.

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More and more, fishery managers worldwide have recognized that as entry or effort controls are increased for one fish species, the bycatch associated with that fishery may be reduced, but there are often negative unanticipated consequences on the economic and/or biological health of other targeted fisheries. This is most likely if the fisheries use similar gear or seasons are complementary. The proper management of fisheries worldwide is becoming more and more important because of the potential for diminished stocks, even to the point of exhaustion. This has significant costs to the development of society, especially in terms of the loss of economic rent. Usually the effects are even more tangible through the price system, as the price for fish rises relative to the price of other meats, which limits food choices. In countries where per capita incomes are low, this can translate into loss of employment and livelihoods, as well as limited access to protein by consumers.

Current approaches to managing fisheries today focus on policies which impose restrictions on gear type, number, and total or individual catches. The implementation of these policies has met with varied success, but improvements in the respective fisheries have occurred due to vigilant monitoring and enforcement, as well as the use of data on the health of fish stocks and fishery inputs and outputs collected by fishers on a regular basis. These positive outcomes, however, require sound political, legal, and management institutions, which are usually absent in many developing countries. However, management of these fisheries cannot be successful without understanding, from a qualitative and quantitative way, the relationships that exist, especially in terms of the kinds of decisions that fishers make in providing output. Estimations of supply functions have not received significant attention in the literature. Even though demand and supply forces interact together with government regulation to provide price and quantity observations in the marketplace, it is important to not assume that price is fixed (as is done in several bioeconomic models), but to identify the determinants of output from the supply side (Nøstbakken and Bjørndal 2003).

The aim of this article is to use the production function approach to analyze the relationship between the harvest of shrimp in Trinidad and Tobago based on aggregate input/output data from 2000–2003. This article is important for the management of shrimp and other fisheries in the Caribbean region, as well as other fisheries that face similar institutional restrictions. It uses the Leontief output supply model and combines the use of effort and relative prices, on a monthly basis, for the three main kinds of vessels in the shrimp industry. This provides an analysis of the importance of effort and the price of shrimp bycatch on the level of shrimp landings.

This article first describes the Trinidad and Tobago fisheries by discussing the evolution of landings of key fish species, fleet structure, and management regulations. The Leontief model is then reviewed. The specification of the model and data used are described. Results of the analysis is then presented and discussed, followed by concluding statements.

## Fishery Sector of Trinidad and Tobago

The fishing industry is characterized by multi-species, multi-gear fisheries. It is largely artisanal, but it is also made up of multipurpose vessels and semi-industrial and industrial trawlers. The most important of the commercial fisheries are reef fish, coastal pelagics, large pelagics, and shrimp. The pelagic species landed for human consumption include Serra Spanish mackerel, king mackerel, and tuna.

Between 1994 and 1998, fish and fishery product imports rose from TT$30.7 mil to TT$44.9 mil (US$1=TT$6.3). The contribution of the fisheries sector to GDP has fallen steadily over time from 0.29% in 1994 to 0.18% in 1999. Trinidad and

Tobago is made up of two islands in the Southern Caribbean (figure 1). While the two islands are constitutionally one, the fisheries are separately managed at the local level. In general, the fisheries are viewed as largely open-access resources.

Vessel registration is required by law. In 2003, there were 830 vessels operating in Trinidad's fisheries. However, unlike vessel registration, fisher registration is not required by law. Therefore, in 2002 there were an estimated 3,500 fishers in the industry, but only 538 were registered.

## *Shrimp Fishery*

Due to an increase in revenue per capita coupled with drastic development of the tourist trade, there has been an increased demand for shrimp in some Caribbean islands, such as Trinidad and Tobago. From 1953 to present day, the shrimp industry in Trinidad has evolved considerably. Prior to 1953, the beach seine was the main gear used. However, after 1953, due to the lack of efficiency of this gear type, in terms of both time and landings, the otter trawl was introduced. Between 1966 and 1969, there was a significant increase in artisanal trawlers (using nets that were retrieved manually) from 66 to 166, contributing to the genesis of the Demersal Trawl Fishery of Trinidad and Tobago. This fishery predominantly targeted white shrimp (*Litopenaeus schmiti*) off the Southwest Coast of Trinidad, which comprises the Gulf of Paria and inshore waters of the Orinoco Delta on the coast of Venezuela.

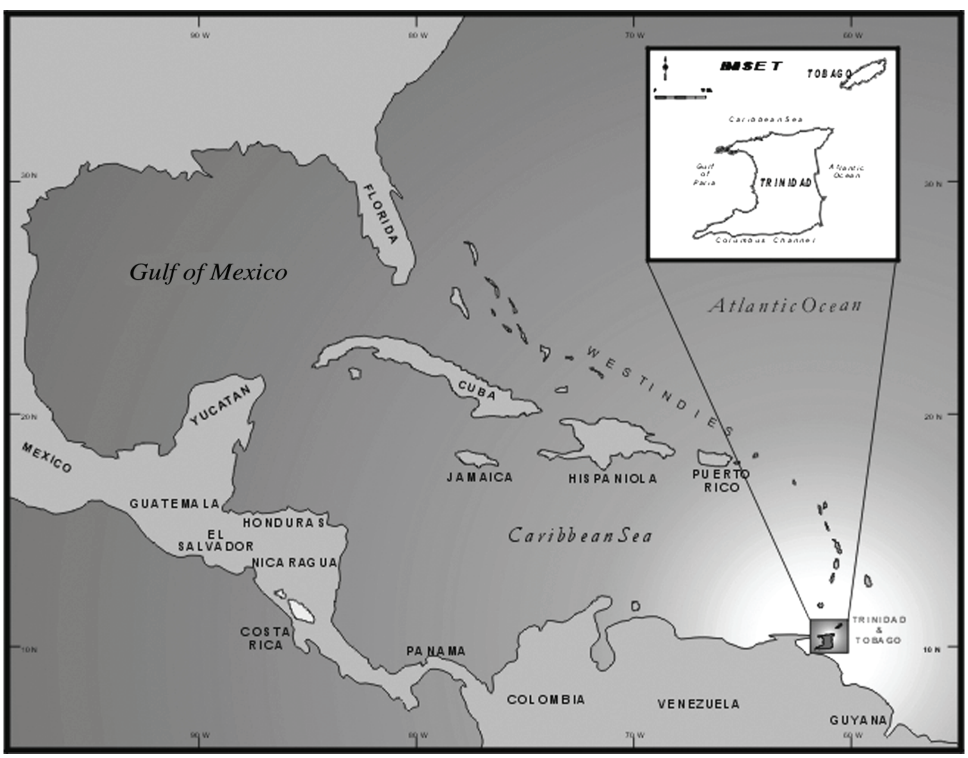


**Figure 1.** Location Map of Trinidad and Tobago
Source: Petrotrin (2007).

In 1977, the governments of Trinidad and Tobago and Venezuela implemented an agreement in which 60 Trinidadian artisanal trawlers were allowed to access the inshore areas of the Delta from December to June each year. In 1985, an additional 10 artisanal trawlers were allowed to access this area; however, all entry was denied by 1995. In 1997, a new reciprocal Fishing "Cooperation" Agreement with Venezuela again allowed access to Venezuelan water outside two miles from the coast. However, ongoing conflicts among fishers and the Coast Guards of both countries resulted in underutilized access (Kuruvilla *et al*. 2000).

In the shrimp fishery, a significant amount of finfish bycatch is harvested. Some of this finfish may be targeted based on market demand, or from July to December when shrimp abundance falls (Maharaj, Ferreira, and Lum Young 1992). Trawlers are categorized based on vessel size and the level of mechanization. In 1979, there were 24 industrial trawlers, and shrimp exports expanded primarily to the U.S.A. There are two inshore, artisanal fleets, one near-shore semi-industrial fleet and one industrial fleet. In 2000, the shrimp fleet was comprised of 114 vessels. Characteristics of these vessels are given in table 1.

All types of trawlers operate on the West Coast throughout the year, primarily from May to August. The next main fishing area is off the South Coast of Trinidad in the Columbus Channel. Since this area lies between Trinidad and Venezuela, Venezuelan trawlers predominantly exploit it (Kuruvilla, Ferreira, and Soomai 2000). Since shrimp move from estuaries as juveniles and slowly migrate to deeper water, the inshore artisanal and off-shore semi-industrial fleets harvest the shrimp at various stages in their life cycle (Kuruvilla *et al*. 2000). Therefore it is important to assess any changes in the effort, landings, and the relationship between these two elements of the fishery for each type of fleet.

**Table 1**
Characteristics and Size of the Trinidad Shrimp Trawl Fleet

| Vessel Type | Average Horsepower | Vessel Length (*m*) | Gear Type | Number of Trawlers (1991) | Number of Trawlers (1998) |
|---|---|---|---|---|---|
| I - Artisanal | 2 × 56 Outboard | 6.7 – 9.8 | 1 stern trawl manually retrieved | 113 | 13 |
| II - Artisanal | 137 Inboard | 7.9 – 11.6 | 1 stern trawl manually retrieved | 66 | 71 |
| III - Semi-industrial | 176 Inboard diesel | 10.4 – 12.2 | 1 stern trawl retrieved by hydraulic winch | 9 | 9 |
| IV - Industrial | 365 Inboard diesel | 17.1 – 22.0 | 2 nets on outriggers retrieved by hydraulic winch | 21 | 21 |
| Total Vessels | | | | 209 | 114 |

Source: Modified from Kuruvilla, Ferreira, and Soomai (2000) and Chan A Shing (1999). The number of semi-industrial and industrial vessels is for 2000.

### *Management*

The main species of shrimp harvested are: brown (*Farfantepenaeus subtilis*); white (*Litopenaeus schmiti*); pink (*F. notialis*); honey or seabob (*Xiphopenaeus*), and red-spotted (*F. brasiliensis*). For all shrimp species, the stock is overexploited, so that the stock biomass is in decline. In addition, recent assessments of the Southern pink shrimp (*Farfantepenaeus notialis*) and Atlantic seabob (*Xiphopenaeus kroyeri*) fisheries indicated that the semi-industrial and artisanal fleets that operate in the Southern Gulf of Paria harvest a significant proportion of juvenile shrimp (Ferreira and Medley 2005)

In 1998, no new trawlers were allowed to enter the fishery; however, this law had limited implementation for only the industrial fleet (Kuruvilla *et al*. 2000). Fishing is permitted in different zones based on the fleet type. However, there is significant overlap in the areas fished by the semi-industrial and industrial vessels in the main fishing area off the West Coast (Kuruvilla, Ferreira, and Soomai 2000). There is a minimum mesh size for the cod-end of the trawl for fish and shrimp, and the use of turtle excluder devices is required by the semi-industrial and industrial fleets. Registered fishers or vessel owners receive Value Added Tax (VAT) exemption on equipment, engine parts, and new fishing vessels. In addition, registered vessel owners who wish to replace their vessels are eligible for a subsidy of 25% of the purchase cost of pirogues to a maximum of TT$5,000. However, the original vessel is required to be removed from the fishery (MALMR 2007). Registered vessel owners are also eligible to access subsidies on gasoline and oil, but these are minimal.

From 1996 to 2005, shrimp landings accounted for an average of 8.8% of all fishery landings (figure 2), and 21.0% of revenue earned annually (figure 3). Overall, the share of landings has fallen from 11.9% in 1996 to 7.0%. Shrimp's share of total revenue declined almost steadily since 1997 from 30% to 16.6%. In 2005, total shrimp landings were 778.67 tonnes, valued at approximately US$3.4 million.

Kuruvilla, Ferreira, and Soomai (2000) reported that between 1995-1998, shrimp exports to the U.S.A. fell significantly and were eventually banned in 1999, since many fishers did not comply fully with U.S. laws, including those pertaining with the use of turtle excluder devices in trawl nets. As an economy, Trinidad and Tobago is presently blocked from exporting wild shrimp to the U.S.A.

The shrimp stock found in Trinidad and Tobago is shared in the Brazil-Guianas Shelf. Therefore, trawling activities in neighboring countries along the northeast coast of South America affects the Trinidad and Tobago fishery (CFRAMP 1997). To assist with management, various stock assessments and bio-economic models of the shrimp species found in Trinidad and Tobago were carried out in the last 15 years. An evaluation of the shared shrimp stocks between Trinidad and Tobago and Venezuela, by the FAO/WECAFC in 2002 indicated the cost per unit of effort (CPUE) for *F. subtilis* fell by 75% between 1970–2002, with a similar decline for *P. brasiliensis*. This, together with other information, indicated that both of these dominant shrimp species were severely overfished (Die *et al*. 2004). Prior stock assessments of *P. subtilis* and *P. schmitti* done in 1990–1991 (CFRAMP 1997) and for *P. subtilis* in 1997 by the WECAFC *Ad Hoc* Shrimp and Groundfish Working Group (FAO/WECAFC 2001), also indicated that these resources were fully to over-exploited and that effort should not increase above the 1996 levels (FAO/WECAFC 2001).

In addition, the stock of *F. notialis* and *X. kroyeri* were also considered to be fully exploited and overfished, respectively, and that very immature, and hence very small, shrimp were being captured (CRFM 2005). A precautionary approach to management was recommended based primarily on a reduction in fleet size and later

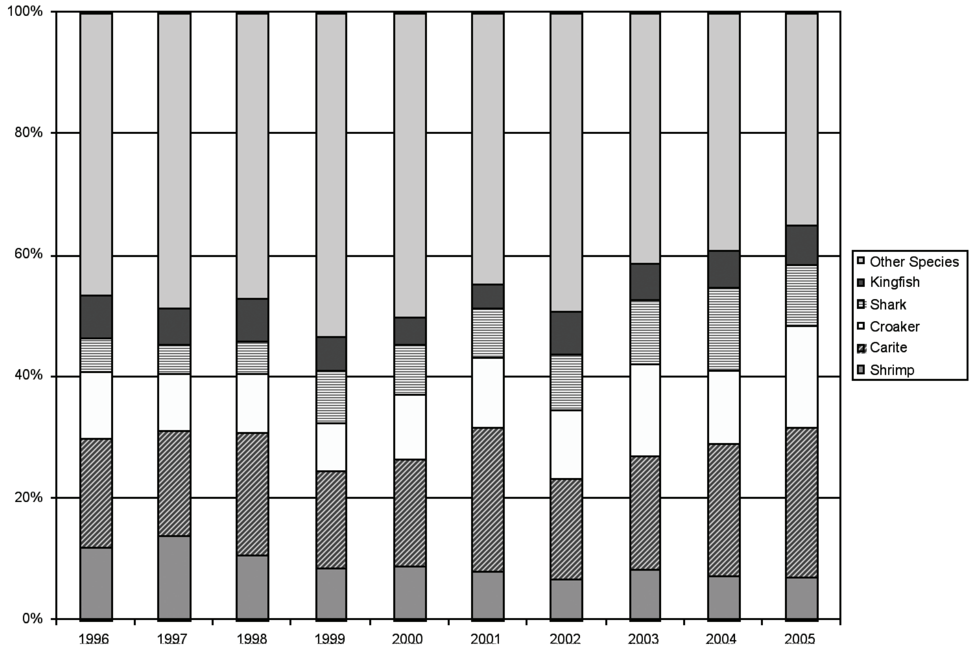


**Figure 2.** Share of Landings for Major Species in Trinidad and Tobago, 1996–2005
Source: Fisheries Division, Ministry of Agriculture, Land and Marine Resources, Trinidad and Tobago.

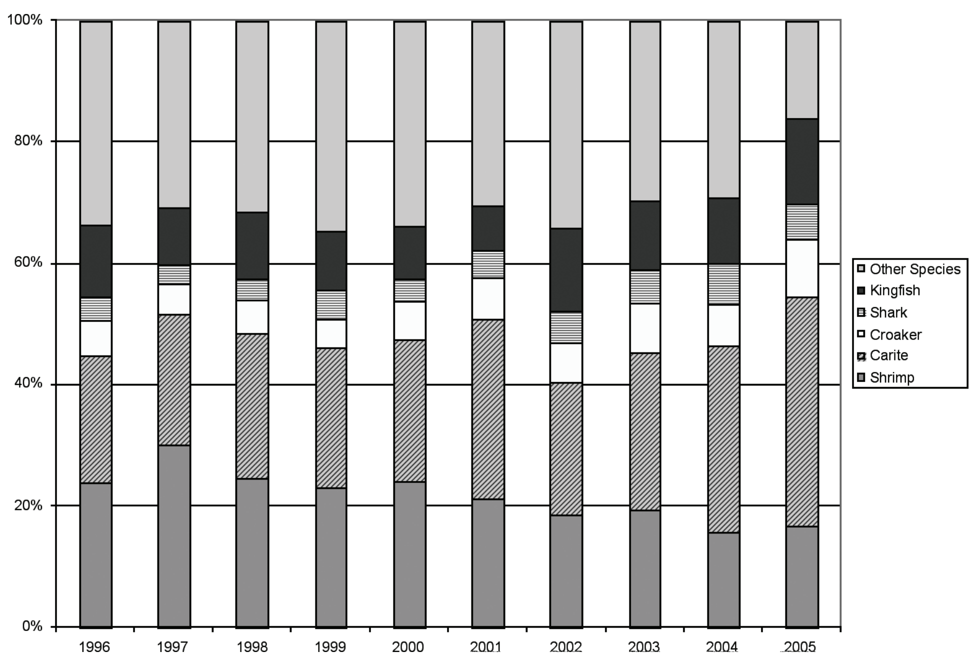


**Figure 3.** Share of Total Revenue by Major Species for Trinidad and Tobago, 1996–2005

supported by a call to introduce closed seasons by countries in the Brazil-Guianas Shelf (FAO/WECAFC 2002).

## Methods

Production functions used to establish the determinants of landings are varied. Recent work has included the use of Cobb-Douglas production functions, where production relies on effort and the stock biomass (Eide *et al.* 1998; García del Hoyo and Chacón 1998). However, the Cobb-Douglas form imposes restrictions on the underlying relationships, such as production elasticity, on substitution possibilities and on the separability of inputs (García del Hoyo and Chacón 1998). More recently, research that assesses the determinants of fish landings has looked at the nature and strength of linkages that exist among fisheries, especially for species that are landed together or at different times of the year by the same group of fishers. This work has primarily used a dual revenue function approach. In the U.S.A., this approach has been used extensively in the U.S. Pacific sablefish and thornyhead fisheries (Squires and Kirkley 1996 and references cited therein) and the New England otter trawl industry, which targets cod, yellowtail, haddock, redfish, and pollock (Squires 1988). The dual approach has also been used to estimate fishery behavior in Australia's multispecies southeast trawl fishery, which lands about 100 commercial fish species (Bose, Campbell, and McIlgorm 2000) and in the Mauritanian (Sahara, West Africa) cephalopod fishery, which is dominated by octopus (Diop and Kazmierczak 1995).

Production technologies used to harvest different species that share inputs are characterized as having jointness-in-inputs, which indicates that changes in the price or level of inputs used in one fishery affect the supplies of other species. It is also possible that there is no direct relationship between any input and output (Kirkley and Strand 1988).

Despite regulations, however, Dupont (1990) found that rent is still dissipated (*i.e.*, uncaptured) from input substitution, fleet redundancy, and/or inefficient fleet composition. For example, regulated inputs (*e.g.*, mesh size) are replaced by unregulated inputs (*e.g.*, labor and vessel horsepower). This substitution lowers the catch per unit associated with the additional capital so that the potential gains in efficiency (such as would result from market-induced input substitution or an efficient regulation) are lost by the increased costs resulting from overcapitalization.

Previous studies have used dual production functions to describe the behavior of firms landing multiple species. These production functions have been derived from profit or revenue functions. Using a "flexible" functional form, which is a second-order differentiable approximation to an unknown function (Blackorby and Diewert 1979), is preferred since it does not limit the values of the substitution elasticities (Greene 1997). Commonly used flexible functional forms for multispecies modeling include the translog (García del Hoyo and Chacón 1998; Thunberg, Bresnyan, and Adams 1995), quadratic (Dupont 1990), and generalized Leontief (Kirkley and Strand 1988; Squires and Kirkley 1995). In multispecies fishery studies that use the dual production function approach, one input use measure is usually fishing effort. Moreover, several researchers have used a "composite input" (a weighted combination of key inputs) as a proxy for all other variable inputs used in the short run.

A nonhomothetic Leontief functional form was selected for this study because it has an advantage of using the data in levels (as opposed to revenue shares), and it automatically imposes linear homogeneity in prices (Squires and Kirkley 1995):

$$R(P,E,D) = \boldsymbol{\Sigma}_k \boldsymbol{\Sigma}_i \boldsymbol{\Sigma}_j \, \beta_{ij}^k \, (P_i P_j)^{1/2} E^k + \boldsymbol{\Sigma}_k \boldsymbol{\Sigma}_n \boldsymbol{\Sigma}_i \, \beta_i^k \, P_i E^k E^n + \boldsymbol{\Sigma}_k \boldsymbol{\Sigma}_m \boldsymbol{\Sigma}_l \boldsymbol{\Sigma}_i \, \alpha_{il}^{mk} D_l^m P_i E^k, \qquad (1)$$

where $R$ is the total revenue per month, $P$ is the unit ex-vessel price of outputs $i,j$ (US$/kg), and $k,n$ are the various types of effort (or restricted input), $E$. Index $l$ represents the categories for each dummy variable, $m$, for the years 2000-2002 and the months of January-November.

The restricted revenue function [equation (1)] was then transformed via Hotelling's Lemma (Diewert 1971) to obtain a system of input-compensated output supply functions:

$$\delta R(P,E,D)/\delta P_i = \Sigma_k \beta_{ii}^k E^k + \boldsymbol{\Sigma}_k \boldsymbol{\Sigma}_{j\neq i} \beta_{ij}^k (P_j/P_i)^{1/2} E^k + \boldsymbol{\Sigma}_k\boldsymbol{\Sigma}_n \beta_i^k E^k E^n + \boldsymbol{\Sigma}_k\boldsymbol{\Sigma}_m\boldsymbol{\Sigma}_l \alpha_{il}^{mk} D_l^m E^k. \tag{2}$$

Since only trip days was used as the measure of effort, the estimable output supply equation for shrimp and bycatch was:

$$Q_i = \beta_{ii} E + \beta_{ij} (P_j/P_i)^{1/2} E + \beta_i E^2 + \boldsymbol{\Sigma}_m\boldsymbol{\Sigma}_l \alpha_{il}^m D_l^m E, \tag{3}$$

where $Q$ represents the quantity of outputs landed (kg). Following estimation, the parameters were used to calculate own- and cross-price elasticities of supply and demand. These elasticities were used to identify substitute or complementary relationships among the outputs. The calculation of cross-price elasticites can be used to determine the level of redirection of effort that may occur if relative prices change (Roderick, Adams, and Taylor 1995). Given the output supply specified in equation 3, the own-price elasticities were calculated as follows:

$$\frac{\partial Q_i}{\partial P_i}\frac{P_i}{Q_i} = \left[\sum_{j\neq i}\left(\frac{-\beta_{ij}E}{2P_i}\right)\left(\frac{P_j}{P_i}\right)^{1/2}\right]\frac{P_i}{Q_i}. \tag{4}$$

*A priori* it is expected that own-price elasticities are positive, reflecting an incentive to increase supplies if faced with higher prices. Similarly, the cross-price elasticities were calculated as follows:

$$\frac{\partial Q_i}{\partial P_j}\frac{P_j}{Q_i} = \left[\left(\frac{\beta_{ij}E}{2}\right)\left(\frac{1}{P_iP_j}\right)^{1/2}\right]\frac{P_j}{Q_i}, \tag{5}$$

*i.e.*, all $\beta_{ij}$'s are simultaneously restricted to a zero value.

Effort elasticities were also computed for a specific month, for each output:

$$\frac{\partial Q_i}{\partial E}\frac{E}{Q_i} = \left[\beta_{ii} + \sum_{j\neq i}\beta_{ij}(P_j / P_i)^{1/2} + 2\beta_i E + \sum_m\sum_l \alpha_{il} D_l^m\right]\frac{E}{Q_i}. \tag{8}$$

## Data

All data were obtained from the Fisheries Division, Ministry of Agriculture, Land and Marine Resources, Trinidad and Tobago. Landings and effort data for all fish species are normally collected in the fishery on a sample basis. For at least 20 random days each month, all trip data is collected at just over one quarter of all landing sites. This data is then used to estimate total trip data (Lalla 2002). The data used in this paper were provided on a monthly basis for all commercial fishers that landed shrimp from 2000–2003. These data included quantity of shrimp and other species (bycatch) landed in live weight (kg), the ex-vessel price (TT$/kg), and the number of trip days per month. Disaggregated data on landings of non-shrimp species were not available. Landings and effort data was divided according to the fleet type: artisanal, semi-industrial, and industrial.

Since the supply equations are derived from a common function, it is possible the error terms are correlated. Therefore, we would expect $E(\varepsilon_i \varepsilon_j') = \sigma_{ij} I_M$, where $\sigma_{ij}$ is the covariance of the disturbances of the $i^{th}$ and $j^{th}$ output equations. This covariance represents the only link between the $i^{th}$ and $j^{th}$ outputs. Because this link is subtle, the system of output supply equations is considered a system of "seemingly unrelated regression" (SUR) equations (Kmenta 1997), with symmetry imposed; *i.e.*, $\beta_{ij} = \beta_{ji}$. Each quarterly system of equations was therefore estimated simultaneously in EViews“ using Zellner's Iterated SUR technique.

## Results and Discussion

Table 2 summarizes the average monthly landings for shrimp and bycatch during the study period. For all fleet types, mean monthly shrimp landings showed some variability, but overall they were stable over time. In contrast, for the artisanal and semi-industrial fleets, the mean unit shrimp price fell steadily from 2000–2003 by 17 and 12%, respectively (table 3). This fall in unit prices may have been due to a decline in the international price for shrimp from 2000–2003, but was opposite to the general rise in the price of food experienced locally, at the rate of 8.3, 13.9, 10.2, and 13.8% in each of the study years, respectively (CBTT 2001, 2003, 2004). The decline in mean ex-vessel price could have also been caused by the landings of a larger proportion of smaller shrimp, which fetch a lower price. Even though the unit price of shrimp increased from 2000–2001 for the industrial fleet, a similar drop occurred thereafter, with similar implications. This reduction in ex-vessel shrimp price was supported by the various stock assessments of the main shrimp species in the fishery, concluding that the shrimp stocks were fully to overexploited (CRFM 2005; CFRAMP 1997; Die *et al.* 2004; FAO/WECAFC 2001, 2002). Further, the pressure on these fisheries appears to be increasing given the continued

**Table 2**
Mean Monthly Landings of the Shrimp Trawl Sample, 2000–2003 (kg)

| | Artisanal | | Semi-industrial | | Industrial | |
|---|---|---|---|---|---|---|
| | Shrimp | Bycatch | Shrimp | Bycatch | Shrimp | Bycatch |
| 2000 | 24,936 | 20,321 | 9,873 | 23,908 | 35,921 | 26,991 |
| 2001 | 32,489 | 15,125 | 10,526 | 21,094 | 34,894 | 33,173 |
| 2002 | 25,725 | 11,984 | 9,556 | 23,651 | 43,052 | 48,104 |
| 2003 | 24,698 | 11,984 | 9,858 | 20,300 | 32,049 | 35,632 |
| Average | 26,962 | 14,854 | 9,953 | 22,238 | 36,479 | 35,975 |

Source: Ministry of Agriculture, Land and Marine Resources (2007).

**Table 3**
Mean Monthly Prices of the Shrimp Trawl Sample, 2000–2003 (US$/kg)

| | Artisanal | | Semi-industrial | | Industrial | |
|---|---|---|---|---|---|---|
| | Shrimp | Bycatch | Shrimp | Bycatch | Shrimp | Bycatch |
| 2000 | 4.46 | 0.67 | 4.82 | 0.74 | 3.94 | 0.85 |
| 2001 | 4.20 | 0.61 | 4.81 | 0.71 | 4.27 | 0.79 |
| 2002 | 3.88 | 0.59 | 4.70 | 0.69 | 4.10 | 0.83 |
| 2003 | 3.68 | 0.58 | 4.22 | 0.70 | 3.81 | 0.78 |
| Average | 4.05 | 0.61 | 4.64 | 0.71 | 4.03 | 0.81 |

Source: Ministry of Agriculture, Land and Marine Resources (2007).

non-implementation of recommendations to reduce the fleet size and introduce season closures. The effects are being reflected in the market price.

The artisanal fleet, which accounts for the majority of vessels in the entire fishery, experienced a steady decline in the average number of trip days from 2001–2003 by almost 34% (table 4). This effort reduction has been partially offset by a 33% rise in mean monthly trips days in the semi-industrial fleet over the same period. No trends were observed for the industrial fleet effort. The artisanal and semi-industrial fleets exhibited very similar patterns of CPUE over the entire sample period (figure 4), but there was no discernable trend in the efficiency of effort over time for these fleets, or the industrial fleet.

The estimated parameters from the output supply equations [equation (3)] are presented in table 5. The base level of dummy variables represents fishing in De-

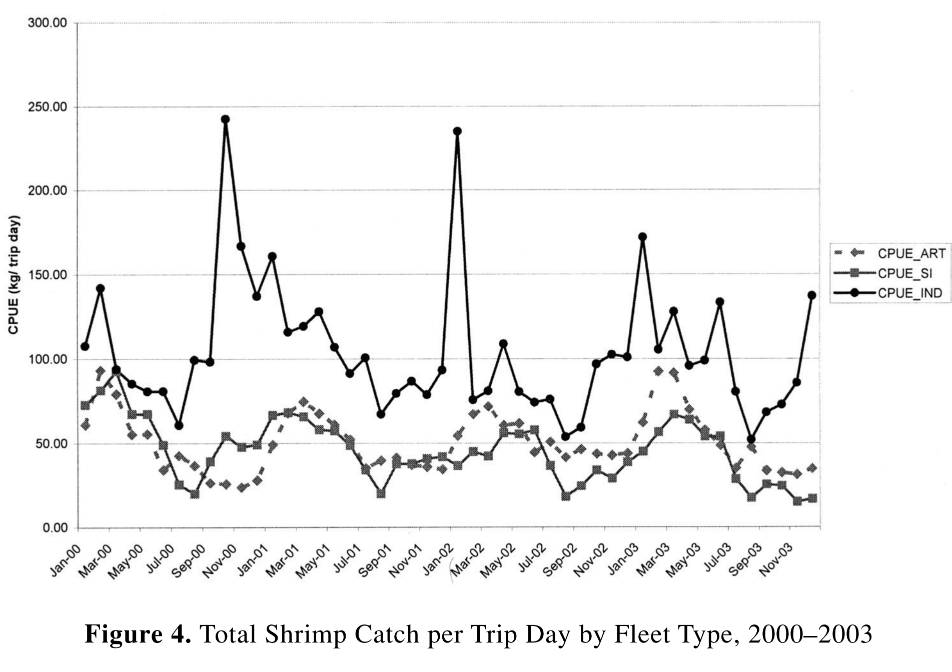


**Figure 4.** Total Shrimp Catch per Trip Day by Fleet Type, 2000–2003

**Table 4**
Mean Monthly Number of Trip Days of the Shrimp Trawl Sample, 2000–2003

| | Artisanal | Semi-industrial | Industrial |
|---|---|---|---|
| 2000 | 567 | 184 | 314 |
| 2001 | 646 | 218 | 348 |
| 2002 | 483 | 241 | 479 |
| 2003 | 428 | 245 | 315 |
| Average | 531 | 222 | 364 |

Source: Ministry of Agriculture, Land and Marine Resources (2007).

cember, 2003. For the artisanal, semi-industrial, and industrial fleets, approximately 40, 34, and 11% of the parameters, which are asymptotically equivalent to maximum likelihood estimates, were significant at the 5% level. For the artisanal fleet, every additional trip day was estimated to increase shrimp landings by approximately 53 kg per month and bycatch landings by approximately 50 kg per month. Even though the additional landings may appear small, what is noteworthy is that almost the same amount of bycatch is estimated to be landed as shrimp. However, as effort increases in the fishery, the rate of change in shrimp landings is expected to fall, but only by a minimal amount.

The coefficient on the relative price variable for both outputs was not significant, which suggests that fishers are not responding to relative price changes in these fisheries. This is counterintuitive in this fishery, where fishers have indicated that the trawl gear is modified in some cases to target finfish which may have a seasonal high value. For the various years, only the 2000 dummy variable was significant for both the shrimp and bycatch supply functions, which suggests that overall there are no annual trends in landings of these species. For the monthly dummies, the coefficients for the months of January to June were significant for both output models in the artisanal fleet. This coincides exactly with the high season for shrimp in Trinidad, and therefore was as expected. While there is expected to be increases in shrimp landings during this high season, the landings of bycatch, as estimated by the model, were expected to fall for those months for every additional unit of effort expended by this fleet. The most important month for shrimp was March. In this month, every additional unit of effort was estimated to increase shrimp landings by almost 46 kg. In contrast, that same additional effort was expected to have a negative impact on bycatch landings, which should fall by 11 kg.

Own-price elasticities for both shrimp and bycatch in the artisanal and semi-industrial fleets had the positive expected signs (table 6). However, in these fleets, the landings of both shrimp and bycatch were largely inelastic. For the artisanal fishers, a 1% increase in the price of shrimp was expected to cause only a 0.02% rise in shrimp landings, and a 1% rise in the price of bycatch was expected to cause only a 0.24% rise in bycatch landings.

In general, the cross-price relationships suggested that fishers were more responsive to changes in the price of shrimp, versus changes in the price of bycatch. This is expected given that the average unit price of shrimp during the sample period is almost five and a half times larger than that of bycatch. However, the responses were still very inelastic.

The effort elasticities, which measure the effects on landings of a unit change in trip days, are shown in table 7 for fishing in each fleet in January of 2003. These

**Table 5**
Estimated Parameters of the Output Supply Equations

| Independent Variables | Outputs (Dependent Variables) Artisanal Fleet Shrimp | Bycatch | Semi-industrial Fleet Shrimp | Bycatch | Industrial Fleet Shrimp | Bycatch |
|---|---|---|---|---|---|---|
| Effort, $\beta_{ii}$ | 53.08* | 50.36* | 25.88 | 154.43* | 113.60* | 59.46 |
| | (6.615) | (13.155) | (16.040) | (51.608) | (27.092) | (63.285) |
| Effort squared, $\beta_{i}$, | –0.02* (0.012) | –0.01 (0.012) | 0.06 (0.049) | –0.10 (0.148) | –0.05 (0.059) | –0.08 (0.068) |
| Output prices, $\beta_{ij}$: | | | | | | |
| Shrimp | SYMMETRIC | | SYMMETRIC | | SYMMETRIC | |
| bycatch | –5.28 | | –18.43 | | 38.74 | |
| | (4.767) | | (20.855) | | (24.581) | |
| Dummy Variables, $a_{il}^{m}$: | | | | | | |
| 2000 | –7.10* | 9.94* | 17.31* | 45.73* | 8.30 | –24.62 |
| | (3.109) | (3.116) | (4.492) | (13.442) | (10.810) | (12.446) |
| 2001 | –1.83 | –2.09 | 8.61* | 16.48 | –1.64 | –16.25 |
| | (3.324) | (3.331) | (3.286) | (9.984) | (10.487) | (12.347) |
| 2002 | –3.45 | –2.11 | –0.87 | 18.37* | –5.75 | 1.05 |
| | (2.795) | (2.804) | (2.768) | (8.258) | (12.734) | (14.609) |
| Jan. | 22.12* | –6.72 | 18.63* | 9.72 | 50.18* | –15.66 |
| | (4.382) | (4.772) | (5.597) | (17.738) | (19.679) | (23.920) |
| Feb. | 43.26* | –8.77 | 26.11* | –11.29 | –10.41 | –6.50 |
| | (4.425) | (5.513) | (5.560) | (17.358) | (17.280) | (20.417) |
| Mar. | 45.63* | –11.22* | 26.05* | –12.06 | –7.41 | 20.77 |
| | (4.420) | (4.980) | (5.643) | (17.708) | (15.597) | (17.870) |
| Apr. | 29.97* | –6.76 | 23.11* | 1.43 | –6.01 | –4.11 |
| | (4.296) | (4.533) | (5.633) | (16.297) | (17.009) | (19.482) |
| May | 25.41* | –4.41 | 22.01* | –9.48 | –19.93 | –4.35 |
| | (4.290) | (4.313) | (5.510) | (15.799) | (15.798) | (18.162) |
| Jun. | 9.69* | –6.82 | 15.53* | –7.63 | –18.55 | –16.15 |
| | (4.426) | (4.465) | (5.370) | (15.557) | (16.481) | (19.585) |
| Jul. | 6.83 | –8.67 | –4.76 | 15.93 | –25.89 | –12.48 |
| | (4.341) | (4.399) | (5.377) | (15.381) | (16.034) | (20.480) |
| Aug. | 6.34 | –11.09* | –19.59* | 12.97 | –46.00* | –1.23 |
| | (4.374) | (4.669) | (5.502) | (17.714) | (16.679) | (20.907) |
| Sep. | 1.68 | –11.43* | –7.59 | –15.07 | –32.02* | –24.41 |
| | (4.490) | (4.543) | (5.487) | (17.079) | (15.870) | (19.771) |
| Oct. | 0.27 | –7.74 | 0.11 | –26.34 | –3.73 | –33.58 |
| | (4.407) | (4.537) | (5.525) | (16.126) | (16.069) | (18.675) |
| Nov. | –1.08 | 7.97 | –3.89 | 10.36 | –7.64 | –14.75 |
| | (4.428) | (4.454) | (5.488) | (15.879) | (17.114) | (19.710) |

Note: A single asterisk denotes statistically significant at the 5% level.

**Table 6**
Own and Cross-Price Elasticities

| | *jth* Species | | | | | |
|---|---|---|---|---|---|---|
| | Artisanal | | Semi-industrial | | Industrial | |
| *ith* Species | Shrimp | Bycatch | Shrimp | Bycatch | Shrimp | Bycatch |
| Shrimp | 0.02 | –0.02 | 0.08 | –0.08 | –0.09 | 0.09 |
| Bycatch | –0.24 | 0.24 | –0.24 | 0.24 | 0.44 | –0.44 |

**Table 7**
Effort Elasticities

| | Artisanal | Semi-industrial | Industrial |
|---|---|---|---|
| Shrimp | 1.02 | 1.43 | 1.44 |
| Bycatch | 0.69 | 0.73 | 0.73 |

elasticities can be computed for any time period, but 2003 was presented here as it represents the most recent study year. Across all fleets, the high season for shrimp landings is from January to June. These elasticities were computed using the variable monthly means for the entire sample period.

For all fleets, effort elasticites for shrimp were elastic, while those for bycatch were inelastic. For every 1% increase in trip days, it is expected that shrimp landings will increase by 1.44 and 1.02% in the industrial and artisanal fleets, respectively. The semi-industrial and industrial fishers reported almost identical responsiveness.

Overall, the use of monthly price and landings data over four years, together with seasonal dummy variables, were included to provide an assessment of the intra- and inter-year variability in the prices of shrimp and bycatch on landings. However, the mixed outcomes of the models, in terms of the significance of the annual dummies and the relative prices, may have been due to the relatively short time series used. This, therefore, suggests that the results are valid only within the range of landings and prices of the sample data. Further, the inclusion of a longer data time series may provide variations in the estimated parameters if the behavior of fishers has changed significantly from that observed during the study period.

## Concluding Remarks

The estimated model suggests that, as expected, the behavior of the different fleet types in the Trinidad and Tobago shrimp fishery is varied. Changes in the nominal prices obtained for the different fleets suggest that fishers may be harvesting smaller, less valuable shrimp over time. Effort is seen as an important determinant in the overall landings of both shrimp and bycatch. While normally seen in a negative way, shrimp fishers are landing significant portions of bycatch and will land even more bycatch as effort increases. The relative price elasticities of shrimp and bycatch do not appear to have any impact on the landings of either species. This is contrary to anecdotal evidence in the fishery, which suggests that fishers modify their gear as the price of finfish increases relative to the price of shellfish.

Other factors in the fishery, such as the importance of bycatch to the local fishing community and the poor success in managing entry into the fishery, also have a great potential impact on the incentives fishers face in determining their landings.

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