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A three essays dissertation on agricultural and environmental microeconomics

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DEDICATION

I would like to dedicate this thesis to my wife Helene without whose support I would not have been able to complete this work. I would also like to thank my friends and family for their loving guidance and financial assistance during the writing of this work.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1. GENERAL INTRODUCTION

Microeconomics is a branch of economics which studies how individual agent behaves unlike macroeconomics which studies the behavior of several agents. By focusing on the behavior of individual sole microeconomics can provide insights and solutions to market failures. This feature has made this branch of economics increasingly important. Even the modern macroeconomics is built upon microeconomics foundation.

This three essays thesis applies microeconomics to answer key issues on agriculture and the management of natural resources. The first essay examines the question of asymmetric information introduced by the emergence of the genetically modified technology in the food system. The second essay looks at the problem of moral hazard in the financing of the rural population in developing countries by supermarket. While these two essays use a theoretical framework to provide insights on concrete issue, the last essay not only develops a microeconomics conceptual framework but also confronts it with real data to understand the behavior of fishermen. In doing so this thesis shows how powerful microeconomics is in understanding the behavior of economic agent and in providing insights to a wide range of question.

Agriculture and the management of natural resources are one the major challenge facing the world in the 21st century.

Increasing consumers concerns toward food safety combined with the introduction of new technology have led to a profound transformation and a differentiation of the marketing channels for food and agricultural products. Furthermore different national regulatory responses to food concerns have entailed a proliferation of food standards and emphasized this phenomenon. Discrepancy in food standard impedes the world trade of agricultural products. This asymmetric information problem is a contentious issue in policy forum across the world.

In particular regulatory responses to the products of the biotechnology have been subject to a lot of controversy from both sides of the Atlantic. While the European Union advocates mandatory labeling based on its precautionary principle, the United State based on the principle of substantive equivalence has argued that there is no need for labeling of these products. The first essay of this paper using a microeconomic model of product differentiation addresses this issue.

The second essay deals with the financing of rural population in developing countries by modern retail chains. Over the last two decades intense competition in developed countries and urbanization in developing countries have led supermarkets to spread in developing countries. The entry of supermarkets in these countries has implication for the entire marketing channel from producer to consumer. In particular to procure the supermarket farmers need to make a substantial up-front investment. There is an intense debate in the literature on whether such investment will exclude or not the smallholders from the marketing channel. The second essay provides a theoretical framework of supermarket procurement organization to understand the implications of this organization on farmers participation in the marketing channel. In doing so this essay fills a theoretical gap in this literature essentially descriptive.

The last essay is concerned with the management of natural resources, especially fisheries. The observed depletion of fish stocks shows the importance to improve the management of fisheries. In the management of fisheries economists and ecologists have taken two different strategies. While economists focus on economic behavior and make simplistic assumptions about the evolution of fish stocks, ecologists have focused on modeling the complexity of the environment of the fishery and ignored the behavioral response of fishermen. Nevertheless the management of fisheries is complex and requires the understanding not only of economic behavior but also of the dynamic of the ecosystem surrounding the fishery. Using recent development in micro econometrics, the last essay of this dissertation provides a more general approach for the management of fisheries. This approach takes simultaneously into account the change in not only environmental but also economics and regulatory conditions surrounding the fishery.

CHAPTER 2. STRATEGIC RESPONSE TO GMOs BY GM-FREE COUNTRIES

Modified from a paper published in the Eureopean Review of Agricultural Economics

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2.1 Abstract

This article examines the dilemma of a large exporting Country for an agricultural product which has to determine whether to approve or not the products of the biotechnology with or without a labeling regime. In doing so this paper makes two points. First the approval decision of the products of the biotechnology is specific to the labeling regime. While the products of the GM technology should be approved under a labeling regime, in absence of labeling requirements they should not be authorized. Second the incapacity to protect the innovator rents can prevent the approval of the products of the biotechnology.

2.2 Introduction

Regulatory responses to the products of the biotechnology have been subject to a lot of controversy from both sides of the Atlantic. While the European Union advocates mandatory labeling based on its precautionary principle, the United State based on the principle of substantive equivalence has argued that there is no need for labeling of these products[1].

[1]See Sheldon (2004) for a comprehensive review of the policy debate between the EU and the US on the regulation of Genetically Modified Organisms (GMOs). On the labeling of GM products see also Caswell (1998), Runge and Jackson (2000), Crespi and Marette (2003), Fulton and Giannakas (2004), Lapan and Moschini (2004) and Veyssiere and Giannakas (2006). Finally on labeling of GM and organic products see Moschini, Bulut and Cembalo (2005) and Giannakas and Yannaka (2006).

Despite the controversy surrounding agricultural biotechnology, the adoption rates of its products have been remarkable. Similarly remarkable has been the concentration of Genetically Modified (GM) production in a small number of large producing countries (James, 2005). As illustrated by the recent debate on the fate of the GM technology in Brazil, a country's attitude towards agricultural biotechnology is shaped to a great degree by a trade off between the expected agronomic benefits from the producer-oriented, first generation of GM crops, and the loss of access to markets with high consumer opposition to GM food products (The Economist, 2003 (a)).

There is little debate that adoption of the new technology and its labeling is an important issue for large exporting countries of agricultural products. Interestingly, despite the importance of this problem, most adoption studies have focused on closed economies and the question of adoption with or without a labeling regime by a large exporting country of agricultural products remains open[2].

The purpose of this paper is to understand and examine the determinants of the approval of the products of the biotechnology. In particular, the paper analyzes and compares the effects of alternative national regulatory decisions on approval and labeling of GM products by a GM free producing country that competes with a GM producing region for access to a world market for an agricultural product.

This study builds on the work by Veyssiere and Giannakas (2006) that analyzes the strategic interactions in labeling decision by GM producing countries in a multicountry context. Unlike Veyssiere and Giannakas (2006), however, our study explicitly accounts for the strategic approval of the products of the biotechnology by a GM-free country.

Furthermore while the focus of this paper and Veyssiere and Giannakas (2006) is on the contentious issue of approval and labeling of GM products, they are not the only factor affecting the development of global market for GM crops and products. Protection of intellectual property rights (IPRs) as well as the costs for regulatory approval are also endogenous to the

[2]To our knowledge, sole Sobolevsky Moschini and Lapan (2005) have examined the effects of approval or not of the product of the biotechnology in an open economy. However their analysis focuses essentially on the impacts on trade of differing national policy for the products of the biotechnology and no specific reason to support approval rather than a ban of the GM technology were advanced.

various countries and can affect the potential of agricultural biotechnology. For developing countries these issues are of crucial importance. Since their incapacity to enforce IPRs due to limited technical and financial capacities, may also limit their regulatory approach toward the products of the biotechnology.

To address these issues the framework develops by Giannakas (2002) in a small economy is extended to a large economy to illustrate the effects of enforcement of IPRs on the approval and labeling decision of the products of the biotechnology.

The most striking result of our analysis is that approval decision appear specific to the labeling regime. Under the condition favorable to a labeling regime a country should favor approval of the GM technology while under the condition favorable to a no labeling regime one country should not authorize the marketing of the GM technology.

Also interesting is that a large economy has in general an incentive to enforce its IPRs. This result is in sharp contrast with the analysis of enforcement of IPRs by Giannakas (2002) for a small economy and has strong implications for the regulatory decision toward the products of the biotechnology of countries without the capacity to enforce IPRs. In particular imperfect enforcement of IPRs can prevent a country from authorizing the marketing of the products of the biotechnology.

The article is organized as follow. The first section discusses the methodology and assumptions employed in our analysis. The second section develops a stylized three region trade model with heterogeneous consumers and producers. The third section examines the approval and labeling decision of the products of the biotechnology. The next section analyses the enforcement IPRs and its implications. The last section concludes the article.

2.3 Methodology and Assumptions

This article develops a stylized trade framework. In this stylized trade framework a supplying country (named hereafter Country 1) is competing with a producing region for access to a world market for an agricultural product. The producing region represents the rest of the producing countries (named hereafter the Rest Of the World: ROW). The ROW is assumed to have approved the product of the biotechnology without any labeling requirement. Producers in both Country 1 and the ROW are assumed to be heterogeneous in terms of the net returns perceived for the different crops. To producers in both Country 1 and the ROW, a set of foreign innovating companies (named hereafter Innovator) are supplying an official GM technology (when approved), while a black market provides smuggled GM seeds to producers (even if not approved). IPRs create economic incentives for research and development by making the innovator the residual claimant of the benefits associated with the new technology. In general infringement of IPRs takes the form of smuggling of illegal GM seeds from a black market by farmers[3]. Finally, on the world market, heterogeneous consumers in terms of preference toward the conventional and GM products make their purchasing decisions, observing the price and the nature of the products supplied.

The focus of our analysis is on the Policy decision of Country 1. This decision is modeled as a two-period sequential game between Country 1, producers and consumers. In the first stage of the game Country 1 determines its agricultural Policy orientation. In the second stage, observing Country 1 decision, consumers and producers make their purchasing and planting decisions, respectively. Country 1 can either approve or not approve the products of the biotechnology and impose or not a labeling regime. As a result four distinct policies emerge:

Policy 1: The GM technology is not authorized and there is no labeling requirement for agricultural products. Since no country labels its products. GM and conventional products are marketed together as a non-labeled good. Given that GM products are credence goods, consumers cannot observe the (GM or conventional) nature of the product supplied.

Policy 2: The GM technology is not authorized and the labeling of agricultural products is mandatory. In that case two separate supply channels one for non-labeled product (supplied by the ROW) and one for product labeled as GM free (supplied by Country 1) will emerge.

Policy 3: The GM technology is authorized and there is no labeling requirement for agricultural products. As in Policy 1 only a non-labeled product will be supplied to the world

[3]For instance Indian agricultural minister Sharad Pawar recently admitted in parliament that there is a flourishing illegal market in GM cotton seeds, strengthening allegations by the industry that more than half of all the GM cotton now growing in the country is from unapproved varieties (Jayaraman, 2004).

market.

Policy 4: The GM technology is authorized and the labeling of the agricultural products is mandatory. Under this Policy, there are three products supplied to the market: the GM-labeled product (supplied by Country 1), the non-labeled product (supplied by Country 2), and the conventional-labeled product (supplied by Country 1).

It is important to understand that while the Policy regime in the ROW is fixed (Approval and No labeling of the GM products: Policy 3) Country 1's Policy decision will affect the nature of its supply as well as the nature of the supply to the world market.

This set of stylized policies captures the great variety of regulations towards GM products observed around the world. As previously mentioned regulations towards the products of the biotechnology are motivated by two distinct approaches: the precautionary principle and the principle of substantive equivalence. The US regulation based on the principle of substantive equivalence does not require any labeling requirement for the products of the biotechnology. Such policy can be captured in our model by Policy 3 and is currently followed by not only the US but also Argentina and Canada. On the other hands Country following the precautionary principle have either authorize the marketing of the products of the biotechnology under a mandatory labeling regime (i.e. Policy 4) or impose a moratorium on these products (i.e. Policy 1). Mandatory labeling policies vary widely in terms of the purity of the GM free product. For instance the EU requires the labeling of GM food and GM ingredients with a 0.9% tolerance level for the adventious presence of GM crops. Australia and New Zealand have mandatory labeling policies at the 1% level of GM ingredient; Japan requires GM food labeling at the 5% level and South Korea has a 3% mandatory requirements. Finally moratoriums of the products of the biotechnology are still in vigor in for instance South Africa, Thailand and Romania (for extensive details on worldwide GM regulations see Center for Food Safety (2006)). Note that to our knowledge no country has imposed a moratorium on GM products along with a labeling regime for its agricultural products i.e. Policy 2.

Given that Country 1 is a producing country, while making its policy choice its objective is to maximize aggregate producer welfare. Therefore to understand its Policy decision, Country

1 level of aggregate producer welfare has to be systematically derived for each Policy.

2.4 The Model

This section presents the methods used to derive aggregate producer welfare under each Policy. For illustration these methods are applied to Policy 4 (Approval and Labeling) that provides the most complex and richest Policy environment.[4].

2.4.1 Supply Side

The production decision of heterogeneous farmers in terms of the net return for different crops is modeled via a framework similar to Fulton and Keyowski (1999); Giannakas (2002) and Chattopadhyay and Horbulyk (2004).

2.4.1.1 Production Decisions in Country 1

Let $A \in \left[0, \overline{A}\right]$ denotes the attribute that differentiates farmers. For tractability, farmers are assumed uniformly distributed between the polar values of A and produce at most one unit. Under Policy 4, farmers in Country 1 are left with the choice to either grow a labeled-conventional crop, a GM-labeled crop or an alternative crop. To each crop a producer with differentiating attribute A associates the following per unit net returns:

- $\pi^4_{gm1} = P^4_{gm} - w_{gm1} + \alpha_1 A$ If one unit of GM crop is produced with official seeds
- $\pi^4_{t1} = P^4_t - w^l_{t1} + \beta_1 A$ If one unit of conventional crop is produced
- $\pi_{a1} = \chi_1 A$ If one unit of alternative crop is produced

In the above equations, P^4_{gm} and P^4_t stand for the per unit price of labeled-GM and labeled-conventional crops under Policy 4, respectively. The parameters w^l_{t1} and w_{gm1} represent the per unit base cost associated with the production of conventional and GM crops, respectively. While the conventional crop receives a price premium (i.e. $P^4_t > P^4_{gm}$); to capture the producer orientation of the first generation of GM products it is more expensive to produce than its GM

[4]the author.

counterpart (i.e. $w_{gm} < w_t$). Finally α_1, β_1 and χ_1 stand for non negative profitability factors associated with the production of GM, conventional and alternative crops, respectively. It is assumed that $\chi_1 > \beta_1 > \alpha_1 > 0$. To simplify notations, let define the difference $\gamma_1 = \chi_1 - \beta_1$ and $\phi_1 = \beta_1 - \alpha_1$ that indicates the degree to which the alternative crop and the conventional crop are more profit effective than the conventional and the GM crop, respectively. One interpretation of $P_t^4 + \beta_1 A$ is that P_t^4 represents the per unit price of the conventional crop received by all farmers growing the traditional crop, while $\alpha_1 A$ represents additional benefits derived by individual A from the production of the conventional crop. These differences in the return stem from such things as geography, education and management skills. A similar interpretation holds for $P_{gm}^4 + \alpha_1 A$.

Furthermore as previously mentioned farmers can smuggle illegal seeds from a black market. In that case the per unit return of a producer with differentiating attribute A is given by:

- $\pi_{s1}^4 = P_{gm}^4 + (\alpha_1 - \tau_{s1}\delta_1) A$ If one unit of smuggled crop is produced

The parameter τ_{s1} stands for the penalty imposed on a farmer, caught using smuggling seeds and $\delta_1 A$ for the audit probability. Following Giannakas (2002) and Chattopadhyay and Horbulyk (2004), the audit probability depends on farm specific characteristics. Hence, less efficient producers (i.e. farmers with low value of A) are more likely to smuggle and thereby to infringe IPRs. As argued by Giannakas (2002) these producers are often located in more secluded area where their land is fragmented in several plot making the audit of the farm more difficult. Furthermore successful producers (i.e. with large value of A) are more exposed to "whistle blowing" by jealous neighbors.[5]

To allow for positive supply of traditional and GM crops it is assumed that:

$\left(P_t^4 - w_{t1}^l\right)(\gamma_1 + \phi_1)/\gamma_1 > P_{gm}^4 - w_{gm1}$. Given that farmers are uniformly distributed and assumed to supply a single unit of output, the farmer indifferent between growing a GM crop

[5]Following Giannakas (2002) and Chattopadhyay and Horbulyk (2004) the smuggling seeds have been assumed to have the same profitability factor. While Morse, Bennet and Ismael (2005) report evidence that farmers using smuggling seeds have lower agronomic performances. They are not certain that this was either due to the specificity of the smuggled seeds or the specificity of the agricultural exploitations. Since they observe that smaller agricultural exploitations are the major user of smuggled GM seeds. A similar observation is reported by Schnepf, Dohlman and Bolling (2001).

and a conventional GM crop determines the quantity of GM products. Graphically this farmer corresponds to the intersection of the net return functions associated with the production of GM and conventional crops (i.e. the farmer with differentiating attribute A^4_{gm1}). Mathematically, the total quantity of GM products supplied is given by:

$$S^4_{gm1} = A^4_{gm1} - 0 = \frac{\left(P^4_{gm} - w_{gm1}\right) - \left(P^4_t - w^l_{t1}\right)}{\phi_1} \tag{2.1}$$

while by the same reasoning the total quantity of agricultural products supplied corresponds to:

$$S^4_{T1} = \frac{P^4_t - w^l_{t1}}{\gamma_1} \tag{2.2}$$

which implies that the quantity of conventional products supplied is:

$$S^4_{t1} = \frac{P^4_t - w^l_{t1}}{\gamma_1} - \frac{\left(P^4_{gm} - w_{gm1}\right) - \left(P^4_t - w^l_{t1}\right)}{\phi_1} \tag{2.3}$$

Note that among the quantity of GM products supplied there is a quantity $S^4_{s1} = w_{gm1}/\delta_1\tau_{s1}$ of products made from illegal smuggled seeds. Finally the total aggregate producer welfare can be expressed as:

$$\Pi^4_1 = \left[\gamma_1 + \frac{\beta_1}{2}\right]\left(S^4_{T1}\right)^2 + \delta_1\tau_{s1}\frac{\left(S^4_{s1}\right)^2}{2} + \phi_1\frac{\left(S^4_{gm1}\right)^2}{2} + \Xi^4 \tag{2.4}$$

Where Ξ^4 corresponds to the surplus derived from the production of the alternative crops under Policy 4.

2.4.1.2 Production Decisions by the Rest of the World

Recall that the Policy regime is fixed in the ROW: approval without any labeling requirements of the products of the biotechnology (Policy 3). Hence producers in the ROW have the choice between planting a non-labeled GM or conventional crop or an alternative crop. The per unit net returns associated with each crop by a farmer with differentiating attribute A can be expressed as:

- $\pi^4_{gm2} = P^4_{nl} - w_{gm2} + \alpha_2 A$ If one unit of GM crop is produced
- $\pi^4_{t2} = P^4_{nl} - w_{t2} + \beta_2 A$ If one unit of conventional crop is produced
- $\pi_{a2} = \chi_2 A$ If one unit of alternative crop is produced

In contrast with a labeling regime no price premium is offered to the production of conventional crops. Farmers receive a per unit price, P^4_{nl}, for the non-labeled crop irrespective of their production choice. Notice that w_t denotes the per unit base costs inherent to the production of the conventional crop under a no labeling regime. Because of the segregation costs incurred under a labeling regime, it is assumed that $w_t < w^l_t$. The relevant quantities are derived following the reasoning already applied to Country 1.[6] The quantity of GM crops is given by:

$$S_{gm2} = \frac{w_{t2} - w_{gm2}}{\phi_2} \tag{2.5}$$

The total quantity supplied corresponds to:

$$S^4_{nl2} = \frac{P^4_{nl} - w_{t2}}{\gamma_2} \tag{2.6}$$

While the total quantity of conventional crops is given by:

$$S^4_{t2} = \frac{P^4_{nl} - w_{t2}}{\gamma_2} - \frac{w_{t2} - w_{gm2}}{\phi_2} \tag{2.7}$$

2.4.2 Demand Side

The methodological framework utilized in the analysis of consumption decisions derives from the models of vertical product differentiation developed by Giannakas and Fulton (2002), Fulton and Giannakas (2004) and Veyssiere and Giannakas (2006). This framework allows for heterogeneous consumers preferences for GM and conventional products.

Let $c \in [0, C]$ be the differentiating attribute that differentiates consumers. For simplicity consumers are assumed uniformly distributed between the polar values of c. Consider a consumer with differentiating attribute c. Under Policy 4, he has the choice of purchasing either a

[6] Again to allow for positive supply of both GM crops and its conventional counterpart it has been assumed that: $\left(P^4_{nl} - w^{nl}_{t2}\right)(\gamma_2 + \phi_2)/\gamma_2 > P^4_{nl} - w_{gm2}$.

labeled GM or conventional product or a non-labeled product or a substitute. Assuming that he only purchases one unit, his utility can be expressed as:

- $U_t^4 = U - \mu c - P_t^4$ If one unit of the conventional product is purchased
- $E\left[U_{nl}^4\right] = U - \left[\mu + \psi_{gm}^4 (\lambda - \mu)\right] c - P_{nl}^4$ If one unit of the non-labeled product is purchased
- $U_{gm}^4 = U - \lambda c - P_{gm}^4$ If one unit of the GM-labeled product is purchased
- $U_s = U - P_s$ If one unit of the substitute is purchased

Where U stands for a per unit base level of utility common to all consumers associated with consumption. P_s stands for the per unit retail price of the substitute product. μ and λ stand for positive utility discount factors associated with the consumption of conventional and GM products, respectively. To capture the expressed consumer's opposition to GM products, it is assumed that $\lambda > \mu$ with the difference $\lambda - \mu$ reflecting the level of consumer's aversion to the GM product. ψ_{gm}^4 stands for the production share of GM products within the supply of non-labeled products, $\psi_{gm}^4 = S_{gm2}/S_{nl}^4$.

Because of the credence attribute of the GM product, consumers are uncertain about the nature of the non-labeled product. Assuming that consumers have rational expectations, the utility derived from the consumption of the non-labeled product is proportional to the production share of GM products into the supply of non-labeled product (ψ_{gm}^4). As a result, the demand is not independent of the supply (on this issue see also Giannakas and Fulton (2002), Fulton and Giannakas (2004) and Veyssiere and Giannakas (2006)).

The consumer with differentiating attribute c_{gm}^4 is indifferent between purchasing the labeled-conventional product and the non-labeled product. Therefore consumers located to the left of c_{gm}^4 prefer purchasing the GM product, while consumers located to the right buy either the non-labeled product or labeled-conventional product or the substitute. Because consumers are uniformly distributed between $[0, C]$, c_{gm}^4 gives the demand for the GM product. Mathematically:

$$D_{gm}^{4} = \frac{P_{nl}^{4} - P_{gm}^{4}}{(\lambda - \mu)\left(1 - \psi_{gm}^{4}\right)} \tag{2.8}$$

The total quantity demanded corresponds to:

$$D_{T}^{4} = \frac{P_{s} - P_{t}^{4}}{\mu} \tag{2.9}$$

The total quantity of the non-labeled product demanded is given by:

$$D_{nl}^{4} = \frac{P_{t}^{4} - P_{nl}^{4}}{\psi_{gm}^{4}(\lambda - \mu)} - \frac{P_{nl}^{4} - P_{gm}^{4}}{\left(1 - \psi_{gm}^{4}\right)(\lambda - \mu)} \tag{2.10}$$

Finally the quantity of the conventional product demanded is given by:

$$D_{t}^{4} = \frac{P_{s} - P_{t}^{4}}{\mu} - \frac{P_{t}^{4} - P_{nl}^{4}}{\psi_{gm}^{4}(\lambda - \mu)} + \frac{P_{nl}^{4} - P_{gm}^{4}}{\left(1 - \psi_{gm}^{4}\right)(\lambda - \mu)} \tag{2.11}$$

2.4.3 Market Outcomes: Aggregate Producer Welfare

Utilizing the supply and demand expressions previously established, the market equilibrium conditions determine the prices and quantities of the relevant products, as well as, the level of aggregate producer welfare. Under Policy 4 there are three markets: one for GM-labeled products, one for non-labeled products and one for conventional-labeled products. The market clearing conditions in each market imply that:

$$D_{t}^{4} = S_{t}^{4} = X_{t}^{4} \tag{2.12}$$

$$D_{nl}^{4} = S_{nl}^{4} = X_{nl}^{4} \tag{2.13}$$

$$D_{gm}^{4} = S_{gm}^{4} = X_{gm}^{4} \tag{2.14}$$

Where X_{t}^{4}, X_{nl}^{4} and X_{gm}^{4} are the equilibrium quantities of conventional, non-labeled and GM products traded in the world market, respectively. Note that under this market scenario

Policies	Level of Aggregate Producer Welfare
Policy 1	$\Pi_1^{1*} = \left[\gamma_1 + \frac{\beta_1}{2}\right] \left(X_{nl1}^1\right)^2 + \left(\phi_1 + \delta_1 \tau_{s1}\right) \frac{\left(S_{s1}^1\right)^2}{2} + \Xi^1$
Policy 2	$\Pi_1^{2*} = \left[\gamma_1 + \frac{\beta_1}{2}\right] \left(X_t^2\right)^2 + \Xi^2$
Policy 3	$\Pi_1^{3*} = \left[\gamma_1 + \frac{\beta_1}{2}\right] \left(X_{nl1}^3\right)^2 + \delta_1 \tau_{s1} \frac{\left(S_{s1}^3\right)^2}{2}$ $+\phi_1 \frac{\left(S_{gm1}\right)^2}{2} + \Xi^3$
Policy 4	$\Pi_1^{4*} = \left[\gamma_1 + \frac{\beta_1}{2}\right] \left(X_{T1}^4\right)^2 + \delta_1 \tau_{s1} \frac{\left(S_{s1}^4\right)^2}{2}$ $+\phi_1 \frac{\left(X_{gm1}^4\right)^2}{2} + \Xi^4$

Table 2.1 Country 1 Payoff Matrix.

Country 1 is the unique supplier of both labeled conventional and GM products, hence X_t^4 and X_{gm}^4 also corresponds to the equilibrium quantity of labeled conventional and GM traded by country 1. Similarly X_{nl}^4 denotes the equilibrium quantity of products supplied by ROW. Substituting back the relevant expressions for the quantities demanded (i.e. equations (2.8), (2.10) and (2.11)) and the quantities supplied (i.e. equations (2.1), (2.3) and (2.6)). Equations (2.12)-(2.14) form a system of three equations with the market equilibrium prices for conventional, non-labeled and GM products as unknown. The solution of this system of equation provides the equilibrium market prices and quantities. Finally, substituting the above equations into (2.4) the level of aggregate producer welfare in Country 1 is given by:

$$\Pi_1^{4*} = \left[\gamma_1 + \frac{\beta_1}{2}\right] \left(X_{T1}^4\right)^2 + \delta_1 \tau_{s1} \frac{\left(S_{s1}^4\right)^2}{2} + \phi_1 \frac{\left(X_{gm1}^4\right)^2}{2} + \Xi^4 \tag{2.15}$$

By repeating the above analysis for the three remaining Policies the Payoff matrix of Country 1 (Table 2.1) can be established. As previously mentioned Country 1 will choose its agricultural Policy by comparing the level of aggregate producer welfare under each Policy[7].

[7] To simplify our analysis, given that the Innovator depicts foreign companies, Country 1 has not been constrained to provide a minimum rent to the Innovator under approval of the GM technology. In practice this needs not to be the case (for details see Giannakas, 2002 and Evenson, 2004). This simplifying assumption, however, does not affect the qualitative nature of our result.

2.5 Approval Decision

In this section two propositions regarding Country 1 approval decision are provided by the analysis of the payoff matrix.

2.5.1 Approval Decision under a No Labeling Regime

Proposition 1: In the absence of any labeling requirement and under the coexistence of the market for GM and conventional products, while with perfect enforcement of IPRs the welfare effects from approval of the GM technology are ambiguous, with imperfect enforcement of IPRs, non approval of the GM technology is the best response of an exporting Country wishing to maximize its aggregate producer welfare.

This proposition is the result of the comparison of Policy 1 and 3 (i.e. Π_1^{1*} and Π_1^{3*}). The reasoning behind proposition 1 is as follow. With perfect enforcement of IPRs (i.e. complete deterrence of smuggling frauds), approval of the products of the biotechnology has ambiguous welfare effects on producers. There is a tradeoff between the producer's benefits from the use of the producer oriented first generation of GM products and the aggregate welfare loss due to lower market price for the non-labeled product caused by a positive consumer aversion. With approval of the GM technology some farmers turn to the production of official GM crops because it is more profitable. As a result the production of GM products in Country 1 increases, which in turn raises the total production share of GM products. This change in the nature of the world supply for non-labeled products will negatively affect consumer belief. Now when purchasing a non-labeled product, consumers believe the likelihood of consuming a GM product is higher. As a result the demand along with the price for non-labeled products will decrease. Such price reduction diminishes aggregate producer welfare in Country 1.

The outcome of this tradeoff is an empirical question and will be determined by: (i) the potential agronomic benefits of the GM technology (i.e. the size of α_1), (ii) the level of market power of the life science sector (i.e. w_{gm1}) and (iii) the strength of consumer aversion (i.e. $\lambda-\mu$) but also by the shape of the distribution of farmers characteristics. In particular a distribution of producers more skewed to the left will put more weight on the benefit from the approval of the GM technology. This result is in accordance with the quantitative analysis of the soybean complex by Moschini and Lapan (2005). In considering a ban of the GM technology by Brazil they report a rise in producer welfare because the price received by Brazilian farmers increased due to consumer aversion.

On the other hand with imperfect enforcement of IPRs (i.e. incomplete deterrence of smuggling frauds) the benefits from approving the products of the biotechnology are limited since producers have already access to the smuggled seeds. In that case of figure the negative welfare effects of the price reduction associated with approval of the GM products are greater than the productivity gain. It is important to understand that this proposition states that under imperfect enforcement of IPRs unofficial approval of the GM technology (since smuggling frauds occur) should be preferred to official approval of the products of the biotechnology in absence of a labeling regime. This means that imperfect enforcement of IPRs can prevent countries to approve the products of the biotechnology.

2.5.2 Approval Decision under a Labeling Regime

Proposition 2: Under coexistence of the market for GM and conventional products, in the presence of a mandatory labeling regime for agricultural products, approval of the GM technology is the best response of a large exporting Country wishing to maximize its aggregate producer welfare.

This proposition is the result of the comparison of Policy 2 and 4 (i.e. Π_1^{2*} and Π_1^{4*}). The reasoning behind this proposition is as follow. With approval of the GM technology, some farmers in Country 1 turn to the production of GM crops because more profitable. As a result the supply to the world market of labeled-conventional products by Country 1 diminishes, while the supply of GM products increases. On the world market, with a labeling regime consumer beliefs about the nature of the product are unaffected by supply changes. Therefore the shifts in Country 1 supplies lead to a reduction in the price of labeled-GM products, while the price premium for labeled-conventional products increases. Thus under Policy 4 the price premium for conventional products will be higher than under Policy 1 because of the presence of the market for GM products. Therefore with a labeling regime the approval of the GM technology is welfare enhancing for all producers in Country 1 and should be Country 1 best response.

This proposition is empirically relevant and can explain both the absence of national regulation imposing a ban or moratorium of the GM products with a labeling regime (i.e. a regulation similar to Policy 2) as well as the recent wave of approval of the GM technology under a labeling regime by the European Union (in April 2004), Brazil (in March 2004) and New Zealand and Australia (in December 2001) to cite a few.

However, it is important to note that proposition 2 assumes that the costs of segregation are similar whether the GM technology has been approved or not. This is a very strong assumption. As noted by Desquilbet and Bullock (2003) the costs of segregation associated with a labeling regime are function of the relative size of the marketing channel for conventional and GM products. Therefore these costs can be expected to be higher in the case of approval of the product of the biotechnology (Policy 4) and thereby to reduce the welfare gain from approval.

2.5.3 Environment Favorable to Approval

According to propositions 1 and 2 approval of the GM technology appears specific of the labeling regime. The environment favorable to alternative labeling regime have already been established and analyzed by Veyssiere and Giannakas (2006). While our model is different from Veyssiere and Giannakas (2006) these discrepancies do not affect the qualitative nature of their results. As in Veyssiere and Giannakas (2006) the main driver of our results is the effect of the production share of GM products in the supply of non-labeled products on consumer beliefs, under a no labeling regime. Because of this externality as the production share of GM products increases on the world market (either because of high profitability of the GM technology in Country 1 and/or the ROW and/or weak IPRs protection in Country 1 and/or the ROW and/or low degree of market power by the life science sector in Country 1 and/or the ROW) the demand and the price for non-labeled products will fall under a no labeling regime. This

Policy 1: Non Approval & No Labeling
High segregation costs
Low consumer aversion
Low profitability of the GM technology
Strong IPRs
High degree of Market Power by the Innovator

Policy 4: Approval & Labeling
Low segregation costs
High consumer aversion
High profitability of the GM technology
Weak IPRs
Low degree of Market Power by the Innovator

Table 2.2 Environment favorable to each Policy.

was true in Veyssiere and Giannakas (2006) and is also verified here. According to equations (2.31) and (2.32), as the quantity of GM products and/or smuggling increases in Country 1 and/or ROW the market price for non-labeled products decreases proportionally in consumer aversion to the consumption of GM products. The reduction in the price of the non-labeled products negatively affect all producers thereby reducing aggregate producer welfare under a no labeling regime. Conversely under a labeling regime, producers will benefit from a more profitable GM technology, a weak enforcement of IPRs and a low degree of market power by the life science sector without suffering any demand loss for their products.

However, Veyssiere and Giannakas (2006) focused on GM producing countries (i.e. a comparison of Policy 3 and 4). Propositions 1 and 2 allow us to extend their results to GM free countries and to characterize the environment favorable to the approval of the products of the biotechnology. This environment is summarized in Table 2.2. This environment is summarized in Table 2.2.

It is important to understand that the conditions presented in Table 2.2 represent depictions of the general environment for approval or not of the products of the biotechnology to be favored by Country 1. Since it is the interaction of all these factors that determines whether approval or not can be Country 1 optimal policy, the conditions presented in Table 2.2 should be viewed as sufficient, and not as necessary, conditions for the different policy to be preferred by Country

1.

Furthermore it is interesting to note that while our analysis assumes that the Country' objective is to maximize domestic producer welfare, the results summarized in Table 2.2 are more general and apply to cases where Country 1 seeks either to maximize its market share on the world market or to maximize aggregate consumer welfare. As shown by Giannakas and Fulton (2002), consumers as a group are better off under a labeling (no labeling) regime when their aversion to GM products is high (low), segregation costs are low (high), and the adoption of the GM technology is high (low). The adoption of the GM technology is high under high profitability of the GM technology (i.e. high α), low market power of the innovating firms (i.e. low w_{gm}), and weak IPRs (i.e. low δ and w_{gm}). With non approval the adoption of the GM technology is obviously minimized. Therefore the conditions reported in Table 2.2 that make approval (no approval) the optimal policy for Country 1 are exactly those that result in approval (no approval) being the policy that maximizes aggregate consumer welfare.

Before concluding this section it is interesting to note that a Country that maximizes the Innovator profit is more likely to choose approval of the product of the biotechnology without imposing labeling requirements (i.e. Policy 3 for detail see propositions 9 of Giannakas (2002)). Such Policy preference is in sharp contrast with our result but not surprising. As noted by Fulton and Giannakas (2004) it is very unlikely that these three groups (consumers, producers and the Innovator) agree on their preferences for the different Policy.

2.5.4 Endogenous IPRs enforcement: Discussion

While our analysis assume that the level of IPRs is given to the country when making its policy choice, in reality Countries also have to determine their level of IPRs enforcement along with approval or not of the products of the biotechnology. According to Table 2.2, Country 1 should be willing to enforce its level of IPRs under a no labeling regime (i.e. Policy 1). Under a no labeling regime, lax enforcement of IPRs increases the productions share of GM products (by increasing the quantity of smuggled seeds, i.e. S^1_{s1}) into the world supply of non-labeled products. As previously explained, this change in the nature of the world supply will negatively affect consumer beliefs. As a result, the demand along with the price for non-labeled product will decrease, which in turn reduces aggregate producer welfare in Country 1. Therefore a country unable to enforce its IPRs regime is more likely to be better off by approving and labeling the products of the biotechnology. However, as noted by an anonymous reviewer it is reasonable to doubt a country's capacity to enforce a label GM free when it cannot prevent the infringement of IPRs. Under a labeling regime identity preservation (IP) systems are necessary to preserve the integrity of the label GM free. As for the protection of the innovator rent, to implement a labeling regime monitoring of the marketing channels from the authority is necessary. In the absence of monitoring because of the credence attribute of the GM products, with a price premium for conventional products, it is by no mean insured that producers will correctly label their products as GM (Gray, Moss and Schmitz, 2004)[8]. Hence, the deterrence of mislabeling frauds and infringement of IPRs are linked and pending on the technical and financial capacity of a country. As a result, a developing country unable to prevent smuggling frauds might not have the capacity to guarantee the integrity of the conventional product, and thus to credibly enforce a label GM free.[9]

Therefore the incapacity of enforcing IPRs may not only prevent a country from approving the GM technology without any labeling requirement as previously mentioned in Proposition 1, but also may limit its capacity to credibly enforce a label GM free. As a consequence, it may also prevent the country to approve the GM technology under a labeling regime.

Before concluding this section note that under non approval of the GM technology, enforcement of IPRs does not only take the form of farm audit but it also includes a stronger monitoring of commodity flows across the border. In this context puzzling regulatory measures such as the refusal of food aid (unless milled) containing GM ingredients by some African countries (such as Angola, Malawi, Zambia and Zimbabwe) can be viewed as regulatory measures motivated by the threat of infringement of IPRs (The Economist, 2003 (b)).

[8]For instance Schnepf, Dohlman and Bolling (2001) reported that 40 % of soybean production was of GM origin, while at that time the use of GM seeds was not authorized in Brazil. This has led the Economist (2003, (a)) to wonder about the credibility and feasibility of a Brazilian label GM free.

[9]See Veyssiere (2006) for a numerical application illustrating this argument and how to account for mislabeling frauds in the present framework.

2.6 Conclusion

This article develops a stylized three-region model of heterogeneous producers and consumers to analyze the best response of a large Country that has to determine the optimal standard for GM products along with the optimal level of IPRs enforcement. Specifically, our analysis utilizes the methodological framework developed in Veyssiere and Giannakas (2006) that analyzes the effect of the strategic interdependence in the labeling decision by GM producing countries. Unlike Veyssiere and Giannakas (2006), however, our study explicitly accounts for a GM free Country having to decide in addition to its labeling Policy whether to approve or not the marketing of GM products. To our knowledge, the approval of the products of the biotechnology by a large GM free country strategically interacting with the Rest of the World has not been considered previously.

The approval decision is modeled in this article as a sequential strategic game played by a large GM free Country having to determine the optimal standard for its agricultural products (adopt or not and/or label or not GM products). In doing so, the article establishes that the approval decision is dependent on the labeling regime. In particular, under conditions favorable to a mandatory labeling regime, approval of the GM technology should be the Country's best response. On the other hand, in the absence of labeling requirements, to not authorize the marketing of GM crops should be the Country's best response.

Moreover, while the recent literature on the economy of IPRs of the products of the biotechnology has focused on a small economy (Giannakas, 2002 and Chattopadhyay and Horbulyk, 2004), this article explicitly considers IPRs infringement in a large economy.

Our results show that in contrast to a small economy, a large economy should benefit from a strong level of IPRs enforcement. However, developing Countries might not have at their disposal the financial and technical capacity necessary to enforce IPRs. As a result the financial burden associated with IPRs and label protection can constitute an impediment to the official adoption of the GM technology. Furthermore their incapacity to deter smuggling can entail severe welfare losses.

In addition to providing insights to Policy makers in their regulatory decision towards GM products, these results rationalize the recent approval by Brazil and the European Union of GM products under a mandatory labeling regime (The Economist, 2003 (a)) as well as the surprising refusal of food aid containing GM products by Ethiopia (The Economist, 2003 (b)). Interesting extension of this research could include the consideration of private actors such as the processing and retailing industry in the approval and enforcement of IPRs.

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CHAPTER 3. A FINANCIAL CONTRACTING APPROACH TO THE ROLE OF SUPERMARETS IN FARMER'S CREDIT ACCESS

Modified from a paper to be published in the American Journal of Agricultural Economics

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3.1 Abstract

In developing countries, moneylenders who lend to farmers monitor them to make sure that their investment is not diverted. Similarly, modern production contracts offered by supermarkets or agro-export firms entail a loan component under the form of input advances and, like traditional moneylenders, supermarkets also want to make sure that this investment is not diverted. However, unlike moneylenders, supermarkets do care about the attributes of the product (form, quality, food safety, etc.). Whether such attributes are present in the harvested product is largely influenced by the advice and the extension services received by the farmer. We built a financial contracting model where we show that supermarkets, choosing to forgo specialization, optimally delegate to a multi-tasking agent both the monitoring and the advisory missions. This contract is shown to potentially enhance credit access for small farmers and sometimes to involve excessive monitoring. Finally, when involved in production, small farmers are shown to benefit the most, even though the supermarket has all bargaining power when making the contract offer.

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3.2 Introduction

In the last two decades, we have witnessed an impressive development of supermarket chains in developing countries. Saturation and intense competition in retail markets of developed countries, together with substantial margins offered by investing in developing markets, have largely contributed to the emergence of supermarket chains.[2] In countries where a substantial portion of the population lives in rural areas, the rise of supermarkets, that arguably affect the livelihood of farmers, is a sensitive issue. Although they represent a source of investment in local economies, their real welfare impacts are hard to assess and remain controversial. On the one hand, many empirical studies have found that supermarkets tend to leave behind or exploit small growers, preferring to concentrate their procurement of fresh agricultural products in larger scale operations (Dolan and Humphrey 2000; Dolan, Humphrey and Harris-Pascal 2001 and Trail 2006).[3] On the other hand, although many growers successfully work with supermarkets, it is not clear whether growers who fail to enter a business relationship with them are worse off relative to the period preceding their entry. In addition, other recent case studies have somewhat challenged the view that supermarkets have only a negative impact on small growers. In particular, these studies show that in niche markets small growers perform remarkably well and remain an attractive supply source for supermarket chains (Boselie, Henson and Weatherspoon 2003; Henson, Masakure and Boselie 2005 and Minten, Randrianarison and Swinnen forthcoming). However, while arguments on both sides are compelling, it is somewhat difficult, in light of these (rather) contradictory observations, to forge a clear understanding of the impact of supermarkets on grower activity. The objective of this paper is to contribute to this debate by providing a theoretical framework to analyze the impact that supermarkets have on growers' credit access.

There exists an important descriptive literature on supermarkets in developing countries.

[2]For instance, Carrefour, a French-based supermarket chain, earned on average three times higher margins in its Argentine operations than in those located in France (Reardon et al., 2003).

[3]While the local demand for food is globally increasing, supermarket chains established in developing countries also export a substantial portion of their production to developed countries (Dolan and Humphrey 2000). Thus, supermarket production will only exclude a portion of the growers that remains uninvolved with the supermarket.

This literature describes and discusses what these retail chains are trying to accomplish and how they achieve their goals. First, it must be noted that besides the growing (local) demand for fresh food products that they try to meet, supermarkets or their affiliated grocers demand a substantially higher quality in the products they procure. Thus, supermarkets not only need to sell more in local markets, but they need to offer safer and higher quality products, as well. Therefore, the natural response of supermarkets has been to develop their own standards in countries where public food quality standards are often inadequate and lack proper enforcement.[4] However, the quest for higher quality and safer food products cannot be achieved without innovative procurement practices. These practices revolve around the creation of vertical relationships with growers through the establishment of tighter procurement contracts. Although the specific form of the contractual relationship between the grower and the supermarket can vary greatly depending on the context, there is arguably a common denominator.

Typically, supermarkets require their growers to make a substantial up-front investment in their operations. This investment ranges from new equipment purchases to the establishment of quality control and coordination systems. The literature analyzing supermarket procurement practices also reports that supermarkets are playing new roles in the production process. These roles essentially consist of a combination of intense production monitoring and advising, sometimes using the support of public partners (Boselie, Henson and Weatherspoon 2003). In practice, the advising is performed on the spot, when supermarket employees visit producers and discuss with them problems encountered during the growing cycle. The typical advice ranges from the proper way to apply fertilizers to the safe handling of pesticides. In addition, supermarkets also take on a monitoring role that essentially protects their investment in the growers' operations. Indeed, the relationship between farmers and supermarkets features a strong moral hazard component. For instance, to certify that product standards are met, but also that procured quantities are sufficient, supermarkets must make sure growers follow specific procedures and do not cheat or misrepresent their efforts and/or actions.[5]

[4]As pointed out by an anonymous reviewer, even with stringent domestic requirements in terms of food standards, supermarkets may still develop their own private standards for two reasons. First via product differentiation, the supermarket can lessen price competition. Second, by imposing high standards requirements, supermarkets may prevent the entry of new competitors.

[5]The most common form of cheating faced by supermarkets is one in which farmers sell part of their crop

Finally, although supermarkets rarely provide cash credit to farmers, they extend loans in the form of input advances that are reimbursed later when the crop is sold.[6] These input loans, which range from seeds to fertilizers and pesticides, cover most of the necessary inputs and their amount can be substantial relative to expected crop payments.[7] Supermarkets also attempt to absorb some of the growers' risks related to market conditions. This is usually achieved by committing to input and output prices prior to planting. Such commitments arguably result in lower liquidity needs for growers and are, in that sense, equivalent to additional loans. Overall, supermarkets' objectives seem to ensure that the financial and production risks faced by their grower base are sustainable and compatible with a long-term dedication to safe and high-quality products (Henson, Masakure and Boselie 2005).

The organization of production by supermarkets, nevertheless, raises several questions. For instance, it is not clear from a theoretical standpoint why supermarkets should provide such a bundle of services. It is conceivable that advising services could be provided independently of input loans. Farmers could finance, possibly using moneylending services, the purchase of the inputs necessary to carry out the production process.[8] Supermarkets would then purchase the crop, provided that it met a certain quality threshold. The mere fact that such organization of production does not prevail in practice suggests that substantial benefits exist in bundling these tasks. In particular, to the extent that supermarkets are keen to have a large grower base for, say, smooth risks, it is possible that this organization of production will allow more farmers to access credit. More generally, we wonder how the emergence of supermarkets will modify credit access for small growers.

Our definition of the supermarket procurement process is very similar to that of contract farming. Production financing in contract farming usually involves technical advising *and* mon-

(for a higher price) to other grocers or local markets and, therefore, do not deliver the quantity that was agreed upon (Gow and Swinnen 2001 and Minten, Randrianarison and Swinnen forthcoming).

[6]Cash advances are, in fact, widespread in transition countries (Gow and Swinnen 2001).

[7]For instance, Boselie, Henson and Weatherspoon (2003) report that it takes a number of plantings for producers to achieve a net overall profit.

[8]In developing countries, credit loans extended by traditional moneylenders use growers' crops as collateral. To make sure that the grower repays his loan, the moneylenders closely monitor him during the crop cycle to make sure that he does not secretly side-sell and then default on their loan by pretending to have a bad harvest (See Aleem 1990 and Hoff and Stiglitz 1998). Unlike advising, the monitoring exerted by the supermarket is very similar to that of traditional moneylending (See Conning 2000 and Minten, Randrianarison and Swinnen forthcoming, for the case of supermarket monitoring.)

itoring. As described by Conning (2000), contract farming, apart from the advising part, is not different from traditional moneylending. In particular, it possesses all the informal aspects of moneylending. This type of lending has become prevalent in many developing countries. For instance, Conning (2000) reports that during the last 20 years production finance has become dominant in Chile. While we rely essentially on the survey of Lecofruit in Madagascar by Minten, Randrianarison and Swinnen (forthcoming), the mechanisms for control and compliance, which either involve contract farming or out-grower schemes, all entail some input lending to farmers. Moreover, in all cases the standard to be achieved by farmers in terms of production are quiet stringent. For instance the EUREP-GAP certification corresponds to the standard followed by European supermarkets.[9] Arguably, this is one of the most stringent standards in terms of quality and safety of food products. Note that in most of the cases, company extension services are in charge of following and guiding farmers during the production cycle. In other cases (Alice and TOPS), advising services are provided by public organizations either for free or for reduced fees.

In this paper, we analyze the market for loans to growers by using a simple model of financial contracting. In our framework, growers need to make a financial investment before they can produce for the supermarket. In addition, during the production process, proper monitoring and advising of growers enhances the likelihood of crop success. We show that an organization in which the supermarket extends a loan and delegates advising *and* monitoring to the same agent is preferred by the supermarket, and also by growers. More precisely, bundling these tasks in the financial contract results in an organization in which motivation costs or agency rents are reduced. This rent contraction results in more poor growers obtaining loans. Our multitasking approach provides a new perspective to apprehend this type of contract and can explain its relative superiority with respect to bank financing or traditional moneylending.

Furthermore, we show that supermarkets have a preference for wealthy farmers. However, this preference is not strictly monotonic and is subordinated to the assumption that the supermarket can make a take-it-or-leave-it offer to the farmer. When hired, small farmers are

[9] It should be noted that some local supermarkets do not always use contract farming, but merely buy standard product at the procurement center back door.

shown to derive strictly positive rents from their relationship with supermarkets. Finally, from a social standpoint, contracts offered by supermarkets might be suboptimal in the sense that they entail excessive monitoring.

In what follows, we briefly present the existing literature on lending in developing countries that is relevant to our work. We also relate our paper to the corporate finance literature on advising and venture capital. The model developed in the main section formalizes the basic idea of bundling advising and monitoring tasks in the same financial contract. We then study growers' incentives in this setup. Finally, we study how standards affect competition in the final market, and thereby influence growers' access to loans.

3.3 Relation to the literature

The literature on moneylending in developing countries starts with the premise that borrowers in developing countries usually have weak balance sheets, and therefore have difficulty accessing financing. Most of the contributions in this field describe mechanisms by which borrowers are able to commit to repay their loans.[10] In the spirit of this literature on financial contracting in developing countries, our main result is to show that, by combining these two tasks, the supermarket allows poorly collateralized growers to obtain a loan; a loan that they would otherwise not obtain. This result is, to the best of our knowledge, novel. Indeed, a few contributions have dealt with contract farming but these contributions remain descriptive in nature (Key and Runsten (1999)). An exception is Swinnen and Vandeplas (2007) who model contact farming as a two-sided moral hazard bilateral relationship. Like us, they show that the farmer can derive a rent from this relationship. However, unlike us they do not discuss credit access as a function of farmer's wealth.

In developing countries, production contracts between exporters or supermarkets on one side and farmers on the other side usually involve loans in the form of an input advance. In this relationship, the supermarkets not only behave as external consultants that provide production advice as to what should be done with the product, but also play the role of

[10] For a good review of the literature on financial contracting in developing countries, we refer the reader to Armendáriz de Aghion and Morduch (2005).

conventional moneylenders.

As investigated by Aleem (1990) and Hoff and Stiglitz (1998), the informal lending activity in developing countries is usually performed by local agents who can easily monitor borrowers. Hoff and Stiglitz (1998), especially emphasize the fact that the moneylending activity is an informationally intensive activity characterized by monopolistic competition. Similarly, our work assumes that supermarkets employ well-informed local agents to perform the monitoring activity.[11] This monitoring activity of supermarket employees is very close in nature to that of moneylenders.[12]

Our work also shares common features with the literature on venture capital. Casamatta (2003) studies under which conditions an entrepreneur (in fact, a borrower) should hire an advisor. Similar to the supermarket agent in our model, when the venture capitalist advises diligently, the probability of a successful project increases. Casamatta (2003) provides a rationale for the existence of venture capitalists by showing that these advisors have to provide funds, as well.

Although the investment scale of the project is quite different, most agro-industries like supermarkets play a role that is, arguably, qualitatively identical to that played by venture capitalists. Indeed, supermarket employees do not limit their activity to monitoring growers; they continuously advise them on best production practices. Moreover, it is well documented that supermarket agents have a specific and substantial knowledge of horticulture and, in that sense, are valuable advisors.[13]

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[11] For instance, Minten, Randrianarison and Swinnen (forthcoming) describe the organization of the procurement activity by retail chains in Madagascar. They write (p. 11):

> Every extension agent, the chef de culture, is responsible for about thirty farmers. To supervise these, (s)he coordinates five or six extension assistants (*assistant de culture*) that live in the village itself. The chef de culture has a permanent salary paid by the firm.

[12] Minten, Randrianarison and Swinnen (forthcoming) also describe the frequency and purpose of the monitoring (p. 12):

> During the cultivation period of the vegetables under contract, the contractor is visited on average more than once (1.3 times) a week. This intensive monitoring is to ensure correct production management as well as to avoid 'side-selling'

[13] Again, Minten, Randrianarison and Swinnen (forthcoming) write:

> The second constraint is human capital and long duration required for training of the *assistants*

From a purely theoretical standpoint, our contribution also relates to recent work on the design of contracts involving multitasking agents. Laux (2001) shows how, in a limited-liability contracting environment, wage cost can be reduced by assigning several independent projects to a single agent rather than to several agents. By paying the agent only when all projects succeed, the principal can relax the agent's limited liability constraint by punishing the agent for a given project by taking away payment on another.

More recently, Hueth and Marcoul (2007) model producer cooperatives by assuming that members provide not only work (as input providers), but also monitor managerial activity (as directors). The resulting multitasking structure is shown to strictly lower motivation costs.

In the next section we develop a sequential model in which every organization choice affects financial contracting outcomes. The financial contract model that we use is similar in spirit to Holmstrom and Tirole (1997).[14] However, unlike the former, our model features an additional advisory task as a key ingredient for project success.

3.4 Procurement organization: a model

Consider a rural economy made up of a population of farmers, an agrifood sector and a financial sector. All the agents of this economy are assumed to be risk neutral. While the agrifood sector involves a supermarket/exporter and a procurement agent, the financial sector involves a bank and a moneylender.

Farmers. Farmers are assumed to be heterogenous in their level of financial capacity, A. The presence of the supermarket provides farmers with the opportunity to develop a production project whose success is stochastic. More precisely, if the project is undertaken, it yields a verifiable income stream of $R > 0$ in case of success and 0 if it fails. ¿From the farmer's perspective, this project requires two inputs: his effort and a fixed-size investment I. When the farmer works diligently, the probability of crop success is raised by p_H. However, diligence

de culture which organize and supervise the contracting farmers in the field. It is estimated that it takes on average two or three years until the firm will be able to give him/her full responsibility in the field. This slows down growth and expansion.

[14] For applications of this framework to developing countries, see Conning (1999).

by the farmer is subject to moral hazard, as he may decide to shirk to enjoy a private benefit B.[15] In this case the farmer does raise at all the likelihood of crop success.

To make the problem non trivial, we assume that $I > A$, so that, in order to operate farmers need to borrow $I - A > 0$ from a financial investor.

The bank. The bank can provide $I - A$ to farmers. The bank is a passive but rational investor; it extends a loan as long as it can recoup it in expectation. It is passive in the sense that it does not have the capacity to supervise borrowing farmers. As a result, banks rely primarily on collateral-based enforcement of their loans. The bank, when accepting farmers' loan applications, cannot observe whether farmers will exert effort or not. In line with Innes (1990) and all of the literature on financial contracting, farmers are assumed to be protected by limited liability; i.e. investors can at most seize the realized outcome. Thus, farmers need to make a credible commitment to the bank on their supply of effort in order for their loan applications to be accepted.

Financing can also be eased by using the services of a procurement agent and a moneylender.

The moneylender. The moneylender is a member of the rural community working for the bank, whose function is to monitor farmers. He has an informational advantage and the bank cannot ascertain whether the monitoring is carried out seriously or not. Therefore, diligent monitoring must be induced through contingent payments. Effective monitoring by the moneylender implies that he privately incurs a cost $m > 0$. Similar to Holmstrom and Tirole (1997), the impact of monitoring is to reduce the farmers' opportunity costs of misbehaving by reducing the benefit of shirking to b, with $B > b$. To make the demand for the moneylender service a viable option, we make the following assumption.

Assumption 1

$$B - b \geq m. \tag{3.1}$$

This assumption simply states that the reduction in the private benefit of the farmer, $B - b$, is greater than the private cost of monitoring, m. Under this assumption, it will be shown later

[15] Based on a survey of Ivory Coast agricultural producers, Biais, Azam, Dia and Maurel (2001) estimate that this opportunity cost of effort is important. Specifically, they report a value for B as large as 40 percent of the investment.

that the compensation left to the moneylender to induce proper monitoring is less than the reduction in the farmer's private benefit. It is intuitive that under this assumption monitoring improves the feasibility of the crop project.[16]

The procurement agent. The procurement agent is also a member of the rural community possibly trained by the supermarket in delivering production advice. This advice helps to bring the product in conformity with the supermarket's specific standards. Effective advising from the procurement agent will raise the probability of success of the project by p_A. In other words, when the advisor and the farmer are both diligent, the probability of crop success is $p_A + p_H$. The advising activity is itself subject to moral hazard, as the procurement agent may prefer shirking on his advising mission to avoid a private cost c. To guarantee a positive demand for service from the procurement agent we make the following assumption.

Assumption 2

$$p_A R \geq \frac{(p_A + p_H)\, c}{p_A}. \tag{3.2}$$

This assumption implies that the value of the project is increased by incurring the advising motivation costs of the agent. Thus, whoever makes the production contract offer always find it optimal to hire a procurement agent. The procurement agent could also be trained by the supermarket in monitoring. Like the moneylender, he may decide to shirk to avoid incurring a private cost m.

The supermarket. The agrifood company has to decide the scope of its activity. The company can hire a procurement agent whose task is simply to advise the farmer. In that case, the financing part is left to the conventional banking sector (here, the bank and the moneylender). The company can also choose to "integrate these tasks under the same roof" by hiring an agent who will both advise and monitor the farmer. In this organizational choice, the monitoring role is assumed by the supermarket agent. As such, the supermarket will replace the bank as a passive investor. For simplicity, the opportunity cost of funds is normalized to 1 for both the bank and the supermarket.

[16]Note that undertaking monitoring implies that the social value of the project is reduced by m. Therefore, from a social standpoint it is a pure loss, and monitoring should be undertaken only if it improves project feasibility.

Finally, we make the following assumption on the parameters:

Assumption 3

$$\max\{p_H R + c, p_A R - c + B\} - I < 0, \tag{3.3}$$

$$(p_H + p_A) R - c - m - I > 0. \tag{3.4}$$

In words, the first condition states that operating the project with a low effort in at least one moral hazard dimension is ruled out. This assumption implies that, in equilibrium, no loan contract that gives one agent incentives to misbehave will be granted. The second condition implies that projects involving monitoring generate a strictly positive surplus.

Summarizing a bit: in the crop production process, diligence in both advising and farming generates a probability $p_H + p_A$ of success, but when shirking on advising and diligence in farming occurs (respectively, diligence in advising and shirking on farming occurs), the probability of success is then p_H (resp. p_A).[17] When shirking occurs on both tasks, crop failure is certain. Lastly, the purpose of monitoring is to lower the farmer's private benefit from B to b.

The interaction between the agents described above is modeled as a four stage sequential game. The timing of events is as follows.

Organizational choice. In the first stage, the supermarket decides between two types of production organization: one in which it hires an agent whose task is solely to advise the farmer on the operation and another in which it hires an agent not only for the advising but also for the monitoring tasks.

Contracting. The agent who holds the bargaining power, the farmer *or* the supermarket, makes a take-it-or-leave-it offer to all the parties involved in the production cycle. More specifically, the offer is a loan agreement specifying a sharing rule according to which, in case of success, the revenue R is divided among all participants. In case of failure, limited liability

[17] This additive specification implies that effort by the farmers and the advisor are not complementary. Instead, each contributes separately to improve the project success likelihood. This assumption certainly simplifies our computation. Introducing some complementarity between the advising and farming tasks would reinforce our main results.

implies that all participants receive 0.[18] If the contract is accepted, the game proceeds to investment; otherwise it ends at this point and all participants are free to consume their initial endowment.[19] Immediately after the contract is signed, the farmer invests A while the bank (or the supermarket, pending on the chosen organization of production in the first stage) delivers $I - A$.[20]

Effort choice. The advisor and the monitor (if one is involved) move first.[21] They simultaneously decide to monitor (or not) and advise (or not) the farmer. The farmer then observes the outcome of the game and, in turn, decides to be diligent or not during the growth cycle.

Production outcome. The production outcome is realized and the return of the project is shared according to the agreement signed at the contracting stage.

The contract design problem consists in optimally sharing the project return, R, without destroying incentives for diligent behavior by the farmer, the moneylender and the procurement agent.

To understand the rationale behind the supermarket's choice of the production organization, the game is solved by backward induction. In the next sections, the optimal contract is systematically established for each potential organization of production; i.e. an organization where the bank finances farmers, the moneylender monitors and the procurement agent advises and an organization where the supermarket finances farmers while the procurement agent monitors and advises farmers. The comparison of the (privately) optimal contracts under alternative organization of production will determine the organization preference of the supermarket. We first begin with the case in which the farmer has all the bargaining power at the contracting stage.

[18] The farmer's net payoff in case of failure is thus $-A$, while it is $-(I - A)$ for the investor.

[19] In the event of the contract being turned down, the farmer would consume A and his net payoff would be 0.

[20] We assume that once I is invested, it is sunk and it has no recovery value in case of failure. This may be the case if the investment is highly specific to the agroindustrial firm or if we are dealing with input advances that are consumed during the growth cycle. However, it is possible to assume that the investment has a salvage value if the project fails. Making a "redeployability" assumption would ease credit access but would not qualitatively modify our results.

[21] For the monitor, this might involve, for instance, observing the farmer's habits or determining before they occur when and where "pirate sales" are likely to happen.

3.5 Monitoring and advising by separate agents: the farmer makes the offer

We consider an organization of production where the supermarket hires the procurement agent to advise, and where financing and monitoring are performed by the bank and the moneylender, respectively. While, according to Assumption 2, farmers always have an interest in requiring an advisor, it is by no means guaranteed that farmers will find it optimal to hire a moneylender. However, for the sake of exposition, we focus on the most general case, where the four parties are involved in production. The farmer has to share the project return with the moneylender, the procurement agent and the bank when formulating the financial contract. This optimal sharing rule can be established by solving the following program

$$\max_{R_f} \{U_f = (p_H + p_A)\, R_f - A\} \tag{3.5}$$

$$R = R_f + R_m + R_p + R_b, \tag{3.6}$$

$$(p_H + p_A)\, R_f \geq p_A R_f + b \tag{3.7}$$

$$(p_H + p_A)\, R_p - c \geq p_H R_p \tag{3.8}$$

$$(p_H + p_A)\, R_m - m \geq p_A R_m \tag{3.9}$$

$$(p_H + p_A)\, R_b \geq I - A. \tag{3.10}$$

Here, U_f denotes the farmer's expected net return from the project, while R_f, R_p, R_m and R_b denote the success-contingent stakes of the project obtained by the farmer, the moneylender, the procurement agent and the bank, respectively.

The first constraint (3.6) states that the project return R is divided among the contracting parties. The following expressions (3.6), (3.7) and (3.8) denote the incentive constraints of the farmer, the procurement agent and moneylender, respectively. As usual in agency models, each constraint requires that the agent earns at least as much from being diligent (i.e. produce effort for the farmer, advise for the procurement agent and monitor for the moneylender) than from shirking. The left-hand sides of (3.6), (3.7) and (3.8) represent the expected net return assuming diligence of the farmer, the procurement agent and the moneylender, respectively. The right hand side of these expressions denotes their expected net returns when shirking.[22]

Finally, the last expression denotes the bank participation constraint. The banking sector is assumed perfectly competitive, and in order to accept a loan application the bank should at least break-even. The left-hand side of (3.10) refers to the expected benefits from lending, while the right-hand side is the market value of the fund supplied by the local bank. Recall that the opportunity cost of funds is normalized to 1.

The solution of the above program is given in the following Proposition.

Proposition 1 [Monitoring and advising by separate agents]: When the organization chosen by the supermarket is such that the bank finances farmers, the procurement agent advises while the moneylender monitors, there exist two thresholds of financial capacity, given by $A_a = I - (p_A + p_H)(R - c/p_A - B/p_H)$ and $A_{am} = I - (p_A + p_H)[R - c/p_A - (b + m)/p_H]$ such that the optimal contract has the following features:

- if $A \geq A_a$, farmers borrow solely from the bank. Their expected net return is given by $U_f^a = (p_A + p_H)[R - c/p_A] - I$,
- if $A_a \geq A \geq A_{am}$, farmers borrow from banks and hire a moneylender. Their expected net return is given by $U_f^{am} = (p_A + p_H)[R - c/p_A - m/p_H] - I$,
- if $A < A_{am}$, farmers do not have access to credit.

This Proposition states that wealthy farmers have an advantage in obtaining loans, as they can bypass the services of the moneylender. In essence, monitoring allows poorer farmer to

[22]Note that the sequential nature of the game is important in interpreting the constraints. For instance, when the farmer deviates from "diligence" in expression (3.7), it is taken into account that the monitor and the advisor have been induced to be diligent. Indeed, when the farmer shirks, his private benefit is b (monitoring is effective) and the probability of success is p_A (the farmer has been advised).

obtain credit. Finally, very poor farmers simply cannot access credit, even though according to Assumption 3, these projects are socially worthwhile. The existence of credit rationing in our context is driven by informational frictions. Indeed, moral hazard, together with limited liability, implies that agency rents have to be distributed to implement the project. This creates a wedge between the social value of the project and the total motivation costs that must be incurred to implement it.

The proof for this result conveys important intuitions useful to understanding the rest of the paper. We therefore give it in the text. Consider first the contract when the farmer decides to hire the supermarket's procurement agent but not the moneylender. Since there is no moneylender, we can set R_m equal to 0 and drop the constraint (3.9). Without monitoring, the private benefit of the farmer when shirking is B. Thus, the farmer's incentive constraint (3.7) is rewritten as

$$R_f \geq \frac{B}{p_H}. \tag{3.11}$$

Likewise, the procurement agent's incentive compatibility constraint (3.8) can be rewritten as

$$R_p \geq \frac{c}{p_A}. \tag{3.12}$$

Substituting back (3.11) and (3.12) into the sharing rule (3.6), the maximum share that can be pledged by the farmer to the bank while applying for a loan is given by

$$R_b^a = R - \frac{B}{p_H} - \frac{c}{p_A}. \tag{3.13}$$

R_b^a is referred to as the pledgeable income. The pledgeable income is the maximum amount that can be credibly promised to investors, i.e. the bank, without destroying the incentives of the agents involved in the financial contract (here, the farmer and the procurement agent).

If the farmer were to pledge more than R_b^a, then the incentive constraint of the farmer (3.11) and/or the procurement agent (3.12) would not be satisfied. As a consequence, the project prospect would be jeopardized and the bank would optimally reject the loan application. More importantly, the pledgeable income creates a lower bound on the level of financial capacity that the farmer must hold to obtain credit. Indeed, substituting back (3.13) into (3.10) leads to

$$A \geq A_a = I - (p_A + p_H)\left[R - \frac{c}{p_A} - \frac{B}{p_H}\right]. \tag{3.14}$$

Thus, farmers with wealth $A < A_a$ cannot convince a bank that they will reimburse the loan entirely, for the latter knows that at least one incentive constraint will be violated.

Recalling that the farmer is residual claimant on the contract, constraints (3.8), (3.9) and (3.10) must be binding, which implies that

$$U_f^a = (p_A + p_H)\left[R - \frac{c}{p_A}\right] - I. \tag{3.15}$$

Not surprisingly, because the moneylending sector is competitive, the farmer captures the surplus of the project *less* the share given to the procurement agent.

Finally, farmers with a level of finance lower than A_a can ask for the supervision of a moneylender to obtain a loan from the bank. Under the supervision of a moneylender, his private benefit from shirking equals b. Hence, assuming proper monitoring by the moneylender, the incentive compatibility constraint of the farmer is rewritten as

$$R_f \geq \frac{b}{p_H}. \tag{3.16}$$

In a sense, by hiring a moneylender, the borrower commits to curtail his share in the project to raise his pledgeable income. However, for the moneylender to effectively monitor, according to (3.9) he should be provided a share of the project such that $R_m \geq \frac{m}{p_H}$.

Following the same logic as before, the pledgeable income, when a moneylender is involved, is

$$R_b^{am} = R - \frac{b}{p_H} - \frac{m}{p_H} - \frac{c}{p_A}. \tag{3.17}$$

Given Assumption 1, $R_b^{am} > R_b^a$ and therefore by hiring a moneylender, the farmer raises his pledgeable income. Substituting (4.17) into (4.10) leads to

$$A \geq A_{am} = I - (p_A + p_H)\left[R - \frac{c}{p_A} - \frac{b+m}{p_H}\right]. \tag{3.18}$$

As expected, by raising the farmers pledgeable income, monitoring reduces the minimum level of financing necessary to obtain a loan.

The expected net return of a farmer under the supervision of the moneylender are then computed as

$$U_f^{am} = (p_A + p_H)\left[R - \frac{c}{p_A} - \frac{m}{p_H}\right] - I. \tag{3.19}$$

Given that a share of the project now has to be forfeited to the moneylender to guarantee proper monitoring, we have $U_f^{am} \leq U_f^{a}$. Therefore, when given the choice between hiring the services of a moneylender or not (i.e. farmers with a level of finance $A \geq A_a$), a farmer will always prefer *not* to hire a moneylender.

Finally, note that the moneylender and the procurement agent will both enjoy a positive expected net return of $\Gamma_{ml} = (p_A + p_H) R_m - m = m p_A / p_H$ and $\Phi_a = (p_A + p_H) R_p - c = c p_H / p_A$ respectively. These positive expected net returns guarantee their participation in the project. This concludes the proof of Proposition 1.

3.6 Monitoring *and* advising by the procurement agent

In this section, we now explore the possibility that the supermarket decides to play the role of the financial sector. To do so, it provides loans to farmers, instructs the procurement agent to monitor the reimbursement of these loans and also trains him to advise farmers on crop matters. In practice, the loan often takes the form of an input advance on seeds, pesticides or fertilizers.[23]

Unlike the previous case, the multitasking nature of the procurement agent now generates several incentive constraints. First, the procurement agent must be given reward R_p, such that

[23] The fact that the supermarket offers inputs rather than cash has several rationales. First, there are economies of scale in procurement; supermarkets or grocers often serve several thousand growers. Second, there is arguably less scope for diversion of physical inputs, although it is still possible that farmers may try to resell them in a secondary market.

he does not want to work on the monitoring task alone. His incentive constraint is written as $(p_A + p_H)\, R_p - m - c \geq p_H R_p - m$,

$$R_p \geq \frac{c}{p_A}. \tag{3.20}$$

Conversely, he should not want to shirk on the monitoring task while working on the advising. Using the same logic, we have

$$R_p \geq \frac{m}{p_H}. \tag{3.21}$$

Finally, the procurement agent can decide to shirk on both tasks, in which case the incentive constraint is written as $(p_A + p_H)\, R_p - m - c \geq 0$ or

$$R_p \geq \frac{m+c}{p_A + p_H}. \tag{3.22}$$

Overall, the procurement agent will be diligent in performing both tasks if constraints (3.20), (3.21), and (3.22) hold true. Thus, the minimum stake consistent with procurement agent diligence is

$$R_p \geq \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A + p_H}\right\}. \tag{3.23}$$

Furthermore, with the procurement agent performing both monitoring and advising, production will involve three agents: the procurement agent, the farmer and the supermarket. In this organization of production, to obtain financing from the supermarket, the contract proposed by the farmer should solve the following program

$$\max_{R_f} \left\{U_f = (p_H + p_A)\, R_f - A\right\} \tag{3.24}$$

subject to

$$R = R_f + R_p + R_s, R_f \geq \frac{b}{p_H}, R_p \geq \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A + p_H}\right\}, (p_H + p_A)\, R_s \geq I - A. \tag{3.25}$$

Here, R_s denotes the share of the project received by the supermarket. Solving the program above gives the following result.

Proposition 2 [Monitoring and advising by the same agent]: When the organization chosen by the supermarket is such that the supermarket finances farmers and the procurement agent advises and monitors, there exist two thresholds of financial capacity, A_a and $A_{am}^S = I - (p_A + p_H)\left[R - \frac{b}{p_H} - \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}\right]$, such that the optimal contract offered by the farmer to the supermarket and the procurement agent has the following features:

- if $A \geq A_a$, farmers borrow solely from the supermarket. Their expected net return is given by U_f^a.
- if $A_a \geq A \geq A_{am}^S$, farmers borrow from the supermarket, which hires a multitask procurement agent.

  Their expected net return is given by $U_f^S = (p_A + p_H)\left[R - \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}\right] - I$.
- if $A < A_{am}^S$, farmers do not have access to credit.

As in Proposition 1, the farmer will not require supervision by the procurement agent if $A \geq A_a$.[24] However, when the farmer has insufficient wealth (i.e., when $A < A_a$), he will accept monitoring by the supermarket agent. Unlike the moneylender, the procurement agent agrees to perform two tasks: monitoring and advising. As previously mentioned, for the procurement agent to be diligent in both monitoring and advising, expression (3.23) should be verified. This implies the following pledgeable income

$$R_s^S = R - \frac{b}{p_H} - \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}. \tag{3.26}$$

Thus, to obtain credit a farmer's level of finance should be such that

$$A \geq A_{am}^S = I - (p_A + p_H)\left[R - \frac{b}{p_H} - \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}\right]. \tag{3.27}$$

Furthermore, by the same reasoning as in Proposition 1, it can be shown that the expected net return of the farmer having access to credit can be expressed as:

$$U_f^S = (p_A + p_H)\left[R - \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}\right] - I. \tag{3.28}$$

[24] In this case, we assume that the loan is extended by the supermarket. In fact, nothing prevents the farmer from borrowing from a bank to finance the inputs necessary for the project.

Finally, it is easy to check that $\Phi_a^S = (p_A + p_H) R_p - m - c \geq 0$ for $R_p = \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}$. Therefore, it is confirmed that the procurement agent always want to participate.

Having established Propositions 1 and 2, it seems natural to inquire about the relative merit of both organizational forms. The next Proposition is the main result of this paper.

Proposition 3 [Monitoring and Advising]: At the first stage of the game, the supermarket (weakly) prefers an organization, in which it finances farmers and hires a procurement agent who both advises and monitors. In this organization, the number of farmers who obtain loans strictly increases in comparison to an organization where advising and monitoring tasks are left to distinct agents.

When the farmer has all bargaining power, the supermarket is indifferent between the two types of organization. However, two (unmodelled) arguments can justify a preference by the supermarket for having a large supply base. First, a supply base of numerous farmers who are geographically dispersed acts as an effective mechanism to reduce the risk of widespread crop failures due to disease and (to a lesser extent) weather. It thus safeguards the ability of the supermarket to fulfill customer orders (Henson, Masakure and Boselie 2005). Second, a large supply base can act as a switching cost reduction mechanism thereby decreasing the search costs for new farmers.

The intuition behind the second part of the Proposition is as follows. Heuristically, by contracting with the same agent on both tasks the supermarket creates an incentive complementarity between the two tasks. For instance, it is possible that the agent derives a substantial rent by, say, monitoring diligently. Bundling and rewarding the two tasks in a single payment enhances incentives, in the sense that the prospect of losing this rent makes the agent less likely to overlook his advising duties. In other words, in this case, the agent is essentially a free advisor. Conversely, the agent could derive a substantial rent in advising and the fear of losing this (advising) rent would essentially make him a free monitor.

Arguably, such a feedback loop does not exist when both tasks are performed by distinct agents. To see this formally, note that the minimum motivation cost necessary to insure proper incentives when advising and monitoring are exerted by separate agents is

$$MS = \frac{c}{p_A} + \frac{b}{p_H} + \frac{m}{p_H}. \tag{3.29}$$

MS is the sum of the farmer, moneylender and procurement agent payments consistent with proper incentives. When both tasks are performed by the same agent, this sum reduces to

$$MB = \frac{b}{p_H} + \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\} < MS. \tag{3.30}$$

Our result points to a beneficial role of supermarkets *for* farmers. However, it is important to note that the occurrence of such contracts results in the disappearance of "traditional" moneylenders in our model. In fact, as already noted by Conning (2000) in the Chilean context, the expansion of contract farming by supermarkets or agroindustrial firms has essentially resulted in the removal of traditional moneylending.

Corollary 1: Farmers prefer an organization of production where the tasks of advising and monitoring are performed by the same agent.

This result is also a direct consequence of the fact that the bundling of both tasks reduces the minimum rent necessary to insure proper incentives. This rent reduction leaves a larger share of the project to be captured by farmers.

3.7 The supermarket holds the bargaining power

So far, all the bargaining power in the contractual relationship was in the hands of the farmers. In reality, the balance of power between farmers and supermarkets arguably leans toward the latter. We now study a situation in which the supermarket holds all the bargaining power and proposes a sharing rule to the farmers and the procurement agent, in order to maximize its expected profits, π. In this contractual relationship, not only should farmers be willing to exert effort, but also to participate. The participation constraint of a farmer is given by

$$U_f = (p_H + p_A)\, R_f - A \geq 0, \tag{3.31}$$

or $R_f \geq A/(p_H + p_A)$. Thus, for the farmer to participate and exert effort it should be that

$$R_f \geq \max\left\{\frac{b}{p_H}, \frac{A}{p_H + p_A}\right\}. \tag{3.32}$$

The problem of the supermarket is expressed as

$$R_s \max\left\{\pi = (p_H + p_A) R_s - (I - A)\right\} \tag{3.33}$$

subject to

$$R = R_f + R_p + R_s, \tag{3.34}$$

$$R_f \geq \max\left\{\frac{b}{p_H}, \frac{A}{p_H + p_A}\right\}, \tag{3.35}$$

$$R_p \geq \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A + p_H}\right\}, \tag{3.36}$$

$$(p_H + p_A) R_s \geq I - A. \tag{3.37}$$

Before we proceed, it is useful to define $R_p^S = \max\left\{\frac{c}{p_A}, \frac{m}{p_H}, \frac{m+c}{p_A+p_H}\right\}$ and $A_I = (p_H + p_A)\left(R_p^S - c/p_A - b/p_H\right)$, that are used in the following result.

Proposition 4: In the second stage of the game, the contract proposed by the supermarket to the farmers and the procurement agent has the following features:

- if $R_p^S = c/p_A$, the farmer accepts a production contract that stipulates monitoring and advising by the procurement agent. The latter earns expected net return Φ_a^S. If
  - $A \geq (p_H + p_A) b/p_H$, the supermarket earns $\pi = (p_H + p_A)[R - c/p_A - b/p_H] - I$, while the farmer has no rent, i.e. $U_f = 0$.
  - $(p_H + p_A) b/p_H > A \geq A_{am}^S$, the farmer's net return is $U_f = (p_H + p_A) b/p_H - A > 0$, while the supermarket's expected profit is $\pi = (p_H + p_A)[R - c/p_A - b/p_H] - (I - A)$.
- if $R_p^S \neq \frac{c}{p_A}$, then the farmer accepts a production contract. If
  - $A \geq (p_H + p_A) B/p_H$, the farmer's net return is $U_f = 0$ and the contract only stipulates advising by the agent who earns Φ_a while $\pi = (p_H + p_A)[R - c/p_A] - I$.

- $(p_H + p_A)\, B/p_H > A \geq A_I$, the farmer's net return is $U_f = (p_H + p_A)\, B/p_H - A > 0$. The contract only stipulates advising by the agent who earns Φ_a while $\pi = (p_H + p_A)\,[R - c/p_A - B/p_H] - (I - A)$.
- $A_I > A \geq (p_H + p_A)\, b/p_H$, the farmer's net return is $U_f = 0$. The contract stipulates monitoring and advising by the agent who earns Φ_a^S. The supermarket's expected profit is $\pi = (p_H + p_A)\left[R - R_p^S\right] - I$.
- $(p_H + p_A)\, b/p_H > A \geq A_{am}^S$, the farmer's net return is $U_f = (p_H + p_A)\, b/p_H - A > 0$. The contract stipulates monitoring and advising by the agent who earns Φ_a^S. The supermarket's expected profit is $\pi = (p_H + p_A)\left[R - R_p^S - b/p_H\right] - (I - A) > 0$.

• if $A < A_{am}^S$, the farmer does not obtain a production contract, i.e., $U_f = 0$.

One of the main findings of Proposition 4 is that loan extension is not influenced by whoever holds the bargaining power. Indeed, as in Proposition 2, loan extension is up to a finance level $A = A_{am}^S$. Thus, this result stems from the delegation to a single agent of the monitoring and advising tasks, *not* from the bargaining power allocation. In our model, the bargaining position of each player only determines how the surplus is allocated among all participants but has no bearing on how many farmers are potentially entitled to produce.

This Proposition also provides insights on a focal issue in the empirical literature on supermarkets, namely the fate of small farmers in the emergence of these agroindustrial companies.

The equilibrium net returns of the farmer and the supermarket are represented as a function of farmers' wealth A. From panel (a), it seems clear that the supermarket has a monotonically increasing preference for well-capitalized farmers. The nature of the relationship explains this result. Indeed, in this relationship, the supermarket is essentially trying to extract diligent care from farmers, using a combination of monitoring services and incentive payments. When misbehaving, relatively wealthy farmers lose their initial outlay A and this is sufficient to keep them on their toes and insure their diligence. With lower initial outlays, poorer farmers stand to lose less from shirking, and the supermarket must insure diligence by relying relatively more on incentive payments, which are costly. This result provides argument for the empirical literature describing the emergence of supermarkets in developing countries, which has forcefully argued that supermarkets tend to contract with large, wealthy farmers, while poorer farmers are left behind (see for instance, Dolan and Humphrey 2000 and Dolan, Humphrey and Harris-Pascal 2001).

Keeping in mind that, after rewarding the agent, the residual project surplus is shared between the supermarket and the farmer, panel (b) is in fact a negative image of panel (a). It shows that even though the supermarket designs the contract, some farmers do obtain a positive surplus from their business relationship with the supermarket. For the reasons explained above, this, in fact, benefits less capitalized farmers. Therefore, the existence of strictly positive rents should attract more farmers. In fact, the long waiting list to enter into the supermarket procurement system observed in many developing countries is at least consistent with this result (on this issue, see Henson, Masakure and Boselie, 2005). If we speculate that a supermarket tries to extend its grower base, then the upper hand of the poorest farmers (i.e., those with level of finance such that $A > A_{am}^S$) should benefit from the implementation of the supermarket arrangement. These findings also seem consistent with recent empirical evidence (Hernández, Reardon and Berdegué 2007).

Although the implementation of such contracts by the supermarket seems to have socially attractive properties, it is by no means clear that they are optimal in the sense that they implement the highest possible surplus.

Corollary 2 [Excessive monitoring]: When $R_p^S \neq \frac{c}{p_A}$ then the supermarket over monitors farmers with a level of finance such that $A_a < A < A_I$. This implies a social loss.

Such supermarket's behavior arises because monitoring effectively transfers a rent from the farmer to it. For a small additional payment, the supermarket assigns the agent an additional monitoring task that ultimately results in (much) smaller incentive payments made to farmers. Here, monitoring is not motivated by feasibility issues, but is just a socially costly rent extraction mechanism. In the light of this theoretical finding, several recent puzzling empirical results may, perhaps, find a natural explanation. For instance, Bellemare (2006) who analyses production contracts between supermarkets and farmers, fails to find strong empirical support for monitoring by supermarkets as a means to raise farmer productivity. Such an observation seems consistent with the result stated above.

Before concluding this section, we must note that an important assumption of our baseline model is arguably the absence of specialization costs. Indeed, we assume that the supermarket agent privately bears cost $m+c$ when performing both tasks. Although it could be argued that synergies might exist between the two tasks, one could also argue that there is convexity in effort cost as the agent performs two tasks. It can be shown that the choice by the supermarket of this type of organization is robust to the introduction of such convexity; that is, socially worthwhile projects that would otherwise be infeasible are undertaken, even though the choice of a single agent is cost inefficient. The supermarket tolerates some inefficiency in the performance of the two tasks, as long as, the reduction in agency costs results in a higher profit.

3.8 Conclusion

This paper explores the peculiar relationship between supermarkets and farmers that exists in developing countries. This relationship is modeled as a financial contract, where the farmer provides effort to the supermarket in exchange not only for technical assistance, but also for credit and infrastructure support. By doing so, we open the "black box" of the supermarket procurement system.

The motivation of the supermarket to provide not only input credits, but also technical assistance in the framework is as follows. By combining monitoring and advising of farmers, supermarkets reduce the agency cost and gain some advantage with respect to conventional moneylenders. This agency cost reduction in turn may widen the scope for financing farmers. This result holds true whether the supermarket or farmers hold the bargaining power. Even more, if the multiplication of the tasks performed entails additional motivation costs, such procurement organization will still be favored by the supermarket and remains potentially conducive to credit extension to smaller farmers. Moreover, this result also provides a rationale for recent empirical evidence that shows that the spread of supermarkets, far from leading to the exclusion of poorer farmers, improves their credit access.

However, the allocation of the bargaining power in the contractual relationship will determine the distributional effects of the spread of supermarkets. In particular, if the bargaining power remains in the hands of the supermarket, we show that the supermarket will prefer targeting the wealthiest producers. The intuition behind this result is as follows. Wealthier farmers make substantially higher investments in the supermarket project. Thus, no financial compensation is necessary to guarantee their diligence, unlike with poorer farmers. It is, thus, more profitable for the supermarket to contract with wealthier farmers. Nevertheless, our results show no reasons, for the supermarket, against the involvement of smallholders in its procurement system. As it can still be profitable for the supermarket to contract with them.

Finally, when given sufficient bargaining power, we find that the supermarket endorses monitoring as a socially costly rent extraction mechanism.

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CHAPTER 4. FISHING BEHAVIOR ACROSS SPACE AND TIME

Modified from a paper to be submitted in the Journal of Applied Econometrics

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4.1 Abstract

Models of fishing behavior rarely incorporate the complexities of marine ecosystems, multiple-stock harvest technologies, and regulations present in real world marine fisheries. We introduce a structural model of a multi-species, weak-output-disposability harvest technology. A latent target-cost-minimizing share vector is estimated to link the technology to a spatially and temporally heterogeneous fish stock. Data from the Gulf of Mexico reef fish fishery is used to estimate the model. The results provide a robust characterization of harvest and discard behavior across space and time. Our approach considerably improves methods used to study fishing behavior and evaluate alternative fisheries management policies.

4.2 Introduction

Fisheries management problems have recently been linked to a reliance on overly simplistic models of marine ecosystems. Single-species management principles that ignore complex biological interactions among multiple species, or multiple age cohorts, and treatment of spatially heterogeneous fish metapopulations as a spaceless whole stocks are examples.[2] A similar critique can be leveled at models of fishing behavior which often exhibit a considerable dis-

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[2]A growing view among fisheries scientists and marine ecologists is that a more holistic approach will improve the management of ocean fisheries resources (Brodziak and Link, 2002; Pikitch et al., 2004; U.S. Commission on Ocean Policy, 2004). The challenges and opportunities that accompany spatial fisheries management are discussed in Wilen (2004).

connect between fundamentals, prices, technologies, stock conditions and regulations, and the fishing outcomes that are of interest to managers. At the least, effective management of fisheries requires information on stocks-specific harvests across space and time, information on bycatch and at-sea discarding, behavioral responses to prices and regulations, and tools to evaluate biological and economic performance of alternative regulatory policies. An essential requirement is that behavioral models be capable of examining the counterfactual, i.e., the behavioral responses of fishermen to regulations that have yet to be adopted. The problem calls for a structural approach that can link management-relevant fishing outcomes to the complex ecological, institutional and economic conditions in marine fisheries.

This paper introduces a novel approach to study the policy-relevant aspects of fishing behavior within a biologically and spatially heterogeneous fishery.[3] Commercial fishermen decide where and when to fish jointly with choices of factor inputs to employ in the harvesting process and the quantity and mix of individual fish species or sub-stocks to harvest. These choices are constrained by the available technology, the composition of the fish stocks and often by various harvest regulations. We introduce a structural economic model that takes as the unit of analysis the spatial harvest and discard choices of fishermen. The model draws heavily on the neo-classical theory of the firm, but is modified to account for the role of the *in situ* fish stocks in the technology. We consider multiple-species, and/or multiple age cohort stocks that are spatially and temporally heterogeneous, and therefore make considerable progress toward incorporating the ecological complexity of real world fisheries.

A key element of our model is a latent vector of target-cost-minimizing harvest shares. This vector summarizes spatial-temporal stock conditions and importantly the spatial-temporal profit opportunities for fishermen. The latent cost share vector provides the crucial link between the technology and the spatially and temporally heterogeneous fish stock. A second key feature is the technology itself, which we assume exhibits a weak-output disposibility property consistent with costly targeting in multiple-species fisheries (Turner, 1995; Singh and Weninger, 2009). Third, our approach controls directly for effects of regulations common in

[3] Berrmann (2007) discusses the various limitations of the random utility model for analyzing spatial fishing behavior. See also Curtis and McConnell (2004).

managed fisheries on fishing behavior.

An application to the Gulf of Mexico reef fish fishery is presented to demonstrate the key attributes. The Gulf of Mexico reef fish fishery is a multiple-species fishery that is managed with seasonal closures for some species stocks, per-trip catch limits, spatial closures, gear restrictions and catch quotas. These regulations along with the weak output disposibility technology lead to a complex decision environment which interacting constraints on the harvest choices of fishermen. Our econometric model incorporates these constraints, in the form of unique Kuhn-Tucker necessary conditions, in the estimation of a parametric multiple-product cost function. The system of estimating equations identifies further the latent stocks conditions that determine the cost structure across space and time. A Gibbs sampler is used to fit the model (see Casella and George, 1992 and Geweke et al., 1999).

Our analysis of reef fish harvest behavior demonstrates several of the model's strengths. We are able to show how prices, and regulation such as per-trip landings limits used to reduce fishing mortality, redirect fishing efforts toward unregulated species and across space and time. Spatial-temporal discard patterns are also impacted by price and regulatory changes. Our model predicts that when the price of fuel rises, reef fish fishermen are less inclined to target higher priced reef fish species, and instead are more inclined to land a harvest mix with low targeting costs. The preferred harvest strategy under higher fuel prices also involves fewer at-sea discards.

Before we present the model and empirical results, it is instructive to compare our approach with related literature. Our model is similar in spirit to state space modeling (see Geweke and Tanizaki, 2001 and for ecological applications see Punt and Hilborn, 1997). Ecologists have long relied on state-space models to estimate latent fish biomass and its underlying dynamics. We do not explicitly model stocks dynamics here; extensions of the model in this direction are discussed in the concluding section. We do adopt some of the econometric techniques used in the ecology literature. Recent advances have shown that Bayesian state space models perform better in the estimation of highly non linear dynamic such as the logistic growth function, which features many fish ecosystems (Wang, 2007).

Current methods for analyzing spatial fishing patterns rely almost entirely on the discrete choice random utility construct.[4] A standard application of random utility models (RUMs) to spatial fishing behavior assumes that on each trip from port, the fisherman selects, from among a set of spatially disjoint (discrete) fishing opportunities or sites, the opportunity that yields the highest utility.[5] Our model also exploits the heterogeneity of the ocean environment for determining spatial behavior, but we do not discretize space or time. The number of sites at which fishermen might deploy gear in a fishery is typically far too large to be estimated via a multinomial probit or multinomial logit specification. This places artificial limits on the number of sites for which preferences may be estimated and forces researchers to assume coarse geographical divisions of the fishing grounds, with coarse descriptions of spatial fishing patterns (Berman, 2007).[6] Our approach of treating space and time continuously is therefore an important advance.

Moreover, application of the RUM to fishing data takes as the unit of analysis the spatial location of a *fishing trip*. A second-stage model of input and output choices on each trip is required by the researcher in order to complete the link between fundamentals and harvests, bycatch revenues and costs. Our model considers the choice of spatial location jointly with the input and harvest choices that are made on the trip. As we demonstrate, this allows us to directly predict management-relevant fishing behavior which is crucial for management purposes.

Estimation procedures that incorporate Kuhn Tucker necessary conditions are common in the analysis of consumer demand systems, and valuation of non-marketed goods (see von Haefen, and Phaneuf, 2007 for a review of this literature). Kuhn Tucker estimation is less common in applied production analysis (an exception is Lee and Pitt, 1987). Whereas in

[4]The random utility model (RUM) was developed by Daniel McFadden to study transportation choices. The original set up assumes that a particular transportation choice yields utility U which is known fully by the decision maker. Utility is decomposed as $U = V + e$, where V is observable by the researcher, while e captures an unobserved component. In empirical applications V may be conditioned on observables such as distance to a destination, average traffic patterns, road conditions, etc.

[5]Numerous applications of the RUM to spatial fishing data have appeared in the resource economics literature. We do not attempt a review of this literature. A special issue of Marine Resource Economics (Volume 19, Number 1, 2004) is dedicated to analysis of spatial fishing behavior. Smith (2000) provides an overview of the RUM method for analyzing spatial fishing data.

[6]Branch et al. (2005) discusses a related problems where the spatial grid used to divide fisheries geographically—typically latitude and longitude designations determined by political considerations—may be unrelated to the locations of productive fishing sites.

demand systems consumer utility is not observable, in our fishing profit maximization problem we observe costs but do not observe the composition of the fish stock at the locations chosen for fishing. We incorporate species-specific KT necessary conditions for optimal harvesting, along with the trip-level cost function. Estimating the system of equations improves parameter identification and directly accommodates the impacts of regulations, e.g., landing constraints that impact our data.

We choose to use Bayesian methods as they present computational advantages over frequentist methods in both fitting non linear equations and estimating random parameters. Markov Chain Monte Carlo (MCMC) methods simulate the posterior but do not maximize the likelihood function (Chernozhukov and Hong, 2003). Bayesian estimation approaches are capable of estimating models for which extremum-based estimators fail to converge. Furthermore in Bayesian frameworks random parameters are accommodated by the appropriate choice of priors. These hierarchical priors introduce an additional structure in the model which eases estimation (Chib and Carlin, 1999).[7,8]

Our model allows for random vessel skipper effects. We adopt a hierarchical prior and use a Metropolis Hasting algorithm to draw from the posterior of our non linear systems of equations (Kim, et al., 2002).[9] Our structural approach unlike Kim, et al. (2002) accommodates not only for lower binding constraints, zero harvests, but also for upper binding constraints on choice variables. In our case the upper-bound constraint is due a per-trip landings regulations imposed by the fisheries management program. To our knowledge this paper is the first to incorporate both types of corner solutions.

The next section presents a multiple-factor input, multiple-species behavioral model in a landings-regulated fishery. Our empirical estimation strategy is also presented. Section 4.4 presents a brief overview of the Gulf of Mexico reef fish fishery, the available data and a

[7]Remark that data augmentation methods (Tanner and Wong, 1987) used for Bayesian inference in RUM greatly eases the computational burden of these models and can significantly extend the location choice set considered (see McCulloch and Rossi, 1994 and Imai and van Dyk, 2005).

[8]While there is no clear advantage in estimating KT systems with either Bayesian or frequentist methods, in the presence of random parameters the Bayesian methods are often preferred (von Haefen and Phaneuf, 2007).

[9]The Bayesian inference approach in Kim, et al., (2002) identifies parameters of consumers preferences for varieties of yogurt. Their procedure remains a reduced form approach because of the absence of data on consumer preferences and thereby only partially identifies behavioral parameters. On the contrary our structural model uses data on the cost function for identification.

discussion of the regulations used to protect reef fish stocks. Section 4.5 reports results and demonstrates use of the model for designing regulatory policies. Section 4.6 summarizes the main insights of the paper and discusses extensions.

4.3 Model

We consider a representative, profit maximizing fisherman who harvests from $i = 1, ..., m > 1$ differentiated fish stocks. Individual stocks can differ by species, age cohort or sex. Denote the non-negative harvest vector as $h = (h_1, ..., h_m)$. The optimization problem is analyzed in two stages; a cost minimization stage followed by a profit-maximizing harvest choice.

4.3.1 Multiple-stocks harvest technology

In a fishery, the cost of harvesting h will depend on factor input prices, but also on the composition, i.e., the absolute and relative abundance of individual fish stocks. We allow the spatial and temporal distribution of the stocks to be heterogenous. Stock composition at a particular location and time can vary depending on the spatial-temporal microhabitat. Abundance at spatial location $s \in S$ and date t is denoted $x_{st} = (x_{1,st}, ..., x_{m,st})$, where $x_{i,st}$ is stock i abundance, and S is the set of all fishing locations on the fishing ground.[10] We assume that harvest h is small relative to stock abundance and treat x_{st} parametrically.

Date t minimum costs are defined as

$$c(h, w, x_{st}) = \min_{v,s}\{w'v|vcanharvesthgivenx_{st},\ s \in S\}, \tag{4.1}$$

where v is a vector of factor inputs (e.g., fuel, bait, ice, labor, and capital), that is purchased competitively at price vector, $w > 0$. We assume the cost function is convex in h and non-decreasing, concave and linearly homogeneous in w. These are *standard* structural properties of multi-product technologies. Additional structural properties unique to fishing technologies are discussed next (see Singh and Weninger, 2009 for further details).

Minimizing the cost of harvesting h will in general involve selecting fishing locations where the composition of the stock is *well-suited* given the harvest target h. To be more precise, if

[10] The spatial location index s may for example, indicate the lattitude, longitude and depth of water column.

a fisherman chooses to harvest a relatively large quantity of stock i fish he will likely select a location at which x_i is abundant in absolute terms and abundant relative to other stocks. At this location, the fishing gear can be expected to intercept stock i in roughly the same proportion as the target vector h. Moving vessels and gear across space utilizes costly inputs. Therefore the fishing location must be optimally chosen jointly with the target harvests to balance costs and benefits of targeting a particular mix of stocks.

Notice that the optimization problem in (4.1) is defined over locations s, whereas the spatial index remains attached to our stock measure, x_{st}. Commercial fishing involves steaming from port to a preferred location and then returning to port to off-load and sell the catch. Vessel operations are mobile and regularly operate from different ports. However, each fishing trip must depart from, and return to some land-based port, and thus the production process is spatially linked to land.[11] Our model allows the costs of accessing a particular stock composition to differ across coarse regions of the fishing ground.

We assume the technology exhibits the non-standard structural property of weak output disposibility (Turner, 1995, 1997; Singh and Weninger, 2009). An important implication of this property is that costs can be non-monotonic in h and specialization, i.e., selecting a harvest mix with $h_i = 0$ for some i and $h_j > 0$ for $j \neq i$, can be costly. To see why this property is reasonable in multiple-stock fisheries, compare the costs associated with the following harvest vectors. The first, denoted h^+, has strictly positive quantities for each species ($h_i^+ > 0$, for all i). The second h^0 is identical with the exception that harvest of the species i stock is zero; $h^0 = (h_1^+, .., h_{i-1}^+, 0, h_{i+1}^+, .., h_m^+)$. Well-suited fishing locations, given the target h^0, may be quite limited since it is likely difficult, maybe impossible, to avoid intercepting some stock i when it is present at a location.[12] Adjusting factor inputs, e.g., changing the mesh size on fishing nets, altering bait and hook configurations, could enhance gear *selectivity* and avoid intercepting stock i when it is present at a location. However these adjustments are expected to be costly.

[11] Researchers have conditioned the location choice on the port from which the vessel departs (Haab et al., 2008). The choice departure and landing port is likely part of a dynamic optimization problem that is a topic of future research.

[12] If the mix of stocks is distributed homogeneously across the fishing ground, and gear is less than fully selective, the set of fishable locations with $x_{i,st} = 0$ and $x_{j,st} > 0$, $j \neq i$ will be empty and $c(h^0, w, x_{st}) = \infty$.

Next compare the costs of harvesting strictly positive vector h^+. It is reasonable that the subset of fishable locations will expand. More generally, fewer factor inputs will be utilized in avoiding stock i fish. The implication is $c(h^+, w, x_{st}) < c(h^0, w, x_{st})$. Although ultimately an empirical question, weak output disposibility, or non-monotonicity of the cost function under stock condition found in most multiple-stock fisheries, is distinctly possible.

Let $c_i \equiv \partial c(h, w, x_{st})/\partial h_i$ denote the marginal cost of harvesting the species i stock at (s, t). The weak output disposibility property is summarized with the following condition.

Condition1: Set $h_j > 0$ for some $j \neq i$, then $c_i(h, w, x_{st}) < 0$ at harvest quantity $h_i = 0$ is permitted.

The above condition implies that there can exist a strictly positive harvest quantity at which marginal cost is zero. Marginal costs are negative at smaller harvests because factor inputs that would otherwise be used to avoid intercepting stock i are saved. Condition 1 implies that marginal rate of output substitution can be positive over a range of harvest levels. It is this property that underlies the bycatch problem in fisheries and under certain regulations provides an incentive to discard fish at sea.

4.3.2 Targeting behavior

We next consider the profit maximizing harvest choices. In many fisheries harvesting activities are subject to stock-specific regulations designed to control total fishing mortality. Following Singh and Weninger (2009), we assume that regulations are directed at the quantities of fish landed at port. Denote landings and discards of stock i as $l_i \geq 0$ and $d_i \geq 0$, respectively. It should be emphasized that the minimum cost function in (4.1) is defined over harvested fish, $h = (l_1 + d_1, ..., l_m + d_m)$.

The regulations we consider are landings constraints that are strictly enforced at the fish dock. We assume that at-sea harvests are unobserved by the manager and are not subject to penalty. Let $\bar{l} = (\bar{l}_1, ..., \bar{l}_m)$ denote the maximum legal landings quantity for stock i fish; $\bar{l}_i = 0$ simulates a closed harvest season for stock i.

The Lagrangian for the profit maximization problem is given as

$$= p \cdot l - c(l + d, w, x_{st}) - \lambda \cdot (l - \bar{l}), \tag{4.2}$$

where $p \in \Re_+^m$ is the output price vector and $\lambda \in \Re_+^m$ is a vector of Lagrange multipliers (vector conformability is assumed). Necessary conditions for optimal landings and discards, denoted l^* and d^*, respectively, are given as

$$p_i - c_i(l^* + d^*, w, x_{st}) - \lambda_i \leq 0, \quad if l_i^* > 0; \quad \lambda_i \left(l_i^* - \bar{l}_i\right) = 0, \quad i = 1, ..., m, \tag{4.3}$$

$$-c_i(l^* + d^*, w, x_{st}) \leq 0, \quad d_i^* c_i(l^* + d^*, w, x_{st}) = 0, \quad i = 1, ..., m, \tag{4.4}$$

$$l_i^* \leq \bar{l}_i, \quad i = 1, ..., m, \quad d_i, \lambda_i \geq 0 \quad i = 1, ..., m, \tag{4.5}$$

Suppose that prices at the dock are strictly positive for the moment, and that the landings constraint does not bind. In this case $\lambda^* = 0$ and the necessary condition in (4.3) indicates the optimal harvest vector satisfies a familiar condition with the price of stock i equal to its marginal cost. We see also that at h^* marginal cost is positive (since $p_i > 0$). Equation (4.4) implies therefore that $d^* = 0$ or alternatively $h^* = l^*$; all harvested fish is landed at port. Under strictly positive prices and no regulation, discarding is not part of a profit maximizing fishing strategy (Turner, 1995).

Now suppose one or more landings constraints bind. Consider first an extreme case where landing stock i is prohibited, $\bar{l}_i = 0$, for example in the case of a stock-specific closure. Assume fishing remains profitable, i.e., $l_j^* > 0$ for some j. Profit maximization requires, $c_i^* = 0$ as indicated in (4.4). An optimal fishing strategy will involve positive discards if marginal costs are negative at zero harvest quantity. Under the weak output disposibility technology it may be less costly to harvest and discard species i fish than take costly efforts to avoid intercepting it with the fishing gear. The implication is that harvests and mortality, unless discarded fish are unharmed, are strictly positive under a stock-specific landings closure. A final observation is that the behavioral implications for a zero dockside price and a landings constraint $\bar{l}_i = 0$ are identical.

Notice further that $c_i^* = 0$ from the necessary condition (4.3). This implies that $\lambda_i^* = p_i$; the shadow price of the stock i landings constraint is equal to the dockside price.

Next consider the case with $\bar{l}_i > 0$ and suppose the landings constraint binds, $l_i^* = \bar{l}_i$. From (4.3) we see that $\lambda_i > 0$ and $p_i > c_i^*$. If discards are positive, $d_i^* > 0$, equation (4.4) requires $c_i^* = 0$, and from (4.3), we see that $\lambda_i^* \geq p_i$. Alternatively, suppose $\bar{l}_i > 0$ and that $d_i^* = 0$. Equation (4.4) requires $c_i^* > 0$, which occurs at strictly positive harvest level, and since $d_i^* = 0$ we have $0 < h_i^* = l_i^* < \bar{l}_i$. However, if the landing constraint does not bind, $\lambda_i^* = 0$, and therefore $p_i - c_i^* = 0$.

The remaining sections estimate a parametric cost function consistent with the structural properties of a costly-targeting technology and the KT necessary conditions for profit-maximizing harvest behavior.

4.3.3 Empirical model

We adopt the following empirical cost function for estimation:

$$c(h, w, s, \varphi_{st}|\gamma, \pi, \beta) = \left[1 +_{i=1}^{m} \gamma_v \left(\theta_i - \varphi_{i,st}\right)^2\right] \cdot g(h, w, s|\beta). \tag{4.6}$$

The function in (4.6) decomposes cost into targeting costs, which are measured by the first bracketed term and non-targeting cost, measured by the function $g\,(.)$. An explanation of the structure and notation used in each component is presented next.

Targeting costs: Notice first that the stock variable, x_{st} has been replaced with the vector $\varphi_{st} = (\varphi_{1,st}, ..., \varphi_{m,st})$, where $\varphi_{i,st} \in [0, 1]$, $i = 1, ..., m$. The vector φ_{st} is a minimum-target-cost share vector for location s and date t. The term $\theta_i = h_i /_{i=1}^{m} h_i$ in (4.6) is the share of stock i fish in the harvest vector. The parameter, $\gamma_v \geq 0$ is a targeting cost parameter for fishermen v. We use V to denote the set of fishermen.

If a fisherman chooses harvest h such that $\theta_i = \varphi_{i,st}$, for all i, the square-bracketed term in (4.6) will equal unity, and harvest costs are given as $g(h, w, s|\beta)$**.** In this case no *targeting* efforts are necessary to harvest the vector h. This is admittedly a stylized construct, since explicit separation of costs into targeting and non-targeting components is difficult to envision in practice. The no-target-cost vector φ_{st} is simply a means to summarize the targeting-relevant features of the fish stock at various (s, t) combinations. Notice that if $\gamma_v > 0$ the term ${}_{i=1}^{m}\gamma_v \left(\theta_i - \varphi_{i,st}\right)^2$ increases with the Euclidean distance between θ and φ_{st}. Therefore harvesting costs rise with the added effort that is required to harvest a mix os species that differs from the mix implicit in φ_{st}.

We allow targeting costs to vary across skippers to allow for heterogeneity in targeting ability which is likely linked to such factors as skipper experience. The parameter γ_v measures the rate at which costs increase for skipper v as the harvest share θ deviates from φ_{st}.

Non-targeting costs: The function $g(h, w, s|\beta)$ is assumed to be strictly positive for $h > 0$, non-decreasing and convex in h, and non-decreasing, concave and linearly homogeneous in w. For our empirical application to the Gulf reef fish fishery g is specified as

$$g = \exp(\beta_0 + \beta_1 h_1 + ... + \beta_m h_m + \beta_s s + \beta_{ss} s^2) \cdot K^{\beta_K} w^{\beta_w}; \tag{4.7}$$

K denotes vessel length and will proxy for the capital endowed to the fishing operation, and w will hereafter denote the price of fuel.

Inclusion of a proxy for capital reflects the short run nature of the harvest problem that we analyze below. Prices for other factor inputs such as bait, ice and groceries, could not be constructed from our data. The crew wage is discussed shortly.

Inclusion of the space index in (4.7), which we enter quadratically, is intended to capture non-targeting cost differences over the fishing ground. Changes in absolute stocks abundance, fishing depths or crew labor quality across regions of the fishery are examples.

The specification in (4.7) is convex in individual stock harvest levels if $\beta_1, .., \beta_m$ are positive. The function is jointly convex in h if ${}_i\beta_i > 0$. The function g is increasing and concave in w if $\beta_w \in (0, 1]$. Linear homogeneity could be easily imposed if multiple-input prices were available. Our data include a single price and therefore the linear homogeneity property is not considered below. If vessel length is a normal input in the production process, harvest costs will be non-increasing and concave in K.

Special cases of the multi-stock targeting technology arise under particular values of γ_v. As $\gamma_v \to \infty$ the technology exhibits fixed output proportions, i.e., costs become infinite unless $\theta = \varphi_{st}$. This case can represent an harvest technology whereby fishermen cannot influence the mix of harvested stocks. Independence across harvested stocks occurs if $\gamma_v = 0$ and $g(h, w, s|\beta)$

is chosen appropriately (see May et al., 1979; Clark, 1990; Boyce, 1996). A test of the null hypothesis, $\gamma_v = 0$ is therefore a test of the structural property of costly targeting (weak output disposibility).

Minimum-target-cost share vector: Estimates of stock specific abundance across space and time is not available in our data, or for any fishery that we are aware of. Therefore the minimum-target-cost share vector is treated as a latent variable that must be estimated. We require a parsimonious specification of the vector φ_{st}. Since s and t are continuous variables, our state space is infinitely large. A curse of dimensionality must be overcome in order to summarize the cost impacts of φ_{st} over space and time. One approach is to discretize the state space, i.e., divide the fishery into subregions and time intervals and assume φ_{st} is constant within each subregion/calendar period combination. This approach has several flaws: (1) the choice of sub-regions and time intervals requires considerable information about spatial-temporal habitat variation; (2) there is no reason to expect φ_{st} changes abruptly at the spatial and temporal boundaries that are chosen, and (3) the number of subregion/calendar period combinations, and therefore unique values of φ_{st} that must be estimated, is likely to be excessive in most fisheries.

Our approach is to assume that spatial and temporal changes in the composition of the fish stocks can be represented by a smooth and continuous function of s and t. We adopt the following functional specification for our estimation:

$$\varphi_{i,st} = \frac{\exp(f_i(s,t|\pi_i))}{1+\exp(f_i(s,t|\pi_i))}, \quad i = 1, ..., m. \tag{4.8}$$

where π_i are parameters to be estimated. The function $f_i(s,t|\pi_i) \in \Re$. The transformation in equation (4.8) ensures $\varphi_{i,st} \in [0,1]$.[13]

In our empirical application f is specified as;

$$f_i(s,t,y|\pi_i) = \pi_{i,0} + \pi_{i,s}s + \pi_{i,ss}s^2 + \pi_{i,y}y + \pi_{i,yy}y^2 + \pi_{i,t}(t-t^2). \tag{4.9}$$

In our empirical application s is a spatial index denoting the geographical subregion of fishing,

[13]Our assumptions for (4.8) do not guarantee that $\sum_i \varphi_{i,st} = 1$ at each (s,t) combination. This does not detract from the model's ability to summarize the minimum targeting costs over space and time.

and t is the day of the year that a fishing trip begins. The variable y is cumulative days since the beginning of our data period. The latent stock share model is therefore capable of capturing spatial and seasonal variation, as well as longer term changes in the composition of the fish stock. The function in (4.9) addresses the dimensionality problem; in our case, characterizing $\varphi_{i,st}$ requires that we identify seven parameters for each of the m fish species/stocks harvested by the fishermen in our data.[14] Note also that the specification in (4.8) provides a framework to test for spatial and temporal variation in the composition of the stocks, e.g., tests of the null hypotheses that f_i is constant across space or time or both (i.e., $f_i(s,t|\pi_i) = \pi_{i,0}$) is easily implemented.

Crew shares: A final consideration is labor remuneration in fisheries data. The lay system by which hired captains and crew are paid a share of trip revenues is ubiquitous in marine commercial fisheries. As pointed by McConnell and Price (2004) the lay system can have implications for fishing behavior. If we denote by η_c the share of trip revenue that is paid to the crew, variable trip profits in (4.2) become: $\eta pl - c(l+d, w, x_{st}) - \lambda \cdot (l - \bar{l})$.

In the above $\eta = 1 - \eta_c$ denotes the residual share of the trip revenue that accrues to the vessel skipper, who we assume is responsible for trip-level harvests decisions. Information on crew shares in our data is incomplete, and we therefore estimate the parameter $\eta = 1 - \eta_c$.

4.3.3.1 Error structure

We assume that the fishermen in our data are aware of φ_{st}, i.e., are knowledgeable about the spatial-temporal composition of the fish stock over the fishing ground.[15] The stock composition is however unobserved by the researcher. Similarly, vessel skipper know their own target cost parameter γ_v. Target costs are unobserved by the econometrician. We assume γ_v is distributed normally in our sample with mean $\bar{\gamma}$ and variance σ_γ^2. $\gamma_v \sim N\left(\bar{\gamma}, \sigma_\gamma^2\right)$.

The estimating equations of our model include the empirical cost function introduced in

[14] Higher-order polynomials and cross terms would increase the flexibility of the model. The added flexibility was deemed to be unnecessary in our application.
Discretizing the *state space* would be problematic with over 21 subregions and roughly 3.75 years of data. For example, if we assume stock conditions are constant during each quarter (year) there would be 345 (92) distinct values of $\varphi_{i,st}$ for $i = 1, ..., m$ to be estimated.

[15] We do not require the assumption that individual fishermen possess knowledge of x_{st} over the entire fishing ground.

equation (4.6), and corresponding Kuhn Tucker necessary conditions for optimal targeting. To simplify notation, we collect the observed data for a representative fishing trip into the row vector $z = [1, h_1, ...h_m, s, w, K, t, y]$. Moreover let $A(z|\gamma, \pi) = [1 + \gamma_v (\theta_i - \varphi_{i,st})^2]$, the marginal cost of harvesting stock i is given as $\mathrm{c}_i (z|\gamma_v, \pi, \beta, \varphi) = \left[\frac{\partial A}{\partial h_i} + A\frac{\partial g}{\partial h_i}\right] g(.) + \varepsilon_i$.

In the above, ε_i, is an error term associated with KT necessary conditions $i = 1, ..., m$. A random term, ε_0 which we assume is distributed $N(0, \sigma_0^2)$ is also appended to our cost function equation (4.6). The random vector $\varepsilon = (\varepsilon_0, \varepsilon_1, ..., \varepsilon_m)$ is assumed normally distributed with zero mean and diagonal covariance matrix Σ.[16] Hereafter, σ_0^2 and σ_i^2 will denote the variance of ε_0 and ε_i, respectively.

The behavioral model introduced above implies the following KT restriction on ε_i:

$$R_i = \begin{cases} \varepsilon_i = c_i (z|\gamma_v, \pi, \beta, \varphi) & if \bar{l}_i = 0 and d_i > 0 \\ \varepsilon_i < c_i (z|\gamma_v, \pi, \beta, \varphi) & if l_i = 0 and d_i = 0 \\ \varepsilon_i = c_i (z|\gamma_v, \pi, \beta, \varphi) - \eta p_i & if 0 < l_i < \bar{l}_i \\ \varepsilon_i > c_i (z|\gamma_v, \pi, \beta, \varphi) - \eta p_i & if l_i = \bar{l}_i \end{cases} .. \tag{4.10}$$

We index the trip level observations with subscript $n = 1...N$. From the KT restrictions in (4.10) and our assumptions for the error terms, the likelihood function for $Z_n = (c_n, z_n)$ is given as

$\mathrm{L}(Z_n|\Gamma) = \phi_0 (\varepsilon_{n0}|0, \sigma_0^2)_{i=1}^{m} \int_{R_{ni}} \phi_i (\varepsilon_{ni}|\sigma_i^2)\, d\varepsilon_{ni}$,where $\Gamma = \{\beta, \gamma_v, \eta, \pi, \Sigma\}$, and R_{ni} reflects the regulatory constraint for stock i on trip n. Letting $Z = \{Z_n\}_{n=1}^{N}$ we have the following likelihood for our data

$$L(Z|\Gamma) =_{n=1}^{N} L(Z_n|\Gamma) \tag{4.11}$$

4.4 The Gulf of Mexico reef fish fishery

The Gulf of Mexico reef fish fishery is a complex of bottom-dwelling species consisting of snappers, groupers, tilefishes, amberjacks, triggerfishes, grunts, porgies, and a host of others. Reef fish fishermen also intercept coastal pelagic species such mackerel, dolphin (wahoo), sharks

[16] Specification of a general covariance matrix (e.g., Kim, et al., 2002) is reserved for future work.

and tuna. The two major gear types in the fishery are vertical hook and line gear and longline gear. The US portion of the fishery extends from the US border with Mexico in the western Gulf to the Florida Keys. There are 21 subregions of the fishery. Hereafter subregions 13-21 will be referred to as the western region, and subregions 1-12 as the eastern region of the reef fish fishery.

The composition of the reef fish stocks varies across western and eastern regions. Groupers are the most important species, by landed pounds and revenue, in the east, with red and gag groupers dominating landings and revenue. National Marine Fisheries Service log book data indicate that red and gag grouper account for 44% of total annual landings, and 50% of annual revenue in the eastern Gulf region (pounds are reported as gutted weight, and prices, revenues and costs are in first quarter 2008 US dollars.) The largest volume and revenue species in the western Gulf region is red snapper which accounts for roughly 49% of the total landed pounds and 59% of total revenue annually.

4.4.1 Data

The data available for analysis are from the National Marine Fisheries Service log book reporting system and a survey of annual operating expenses that was conducted by the Southeast Fisheries Science Center. Regulations require that following each reef fish trip, vessel operators record harvests by species, gear type used, primary subregion of fishing, number of crew on board the vessel and other trip characteristics. In 2003, a "Trip Expense & Payment Section" was added to the logbook form which recorded revenue by species, and expenses for fuel, bait, ice, and food. Beginning in 2005, expense and payment data collection became mandatory for a stratified sample of the permitted reef fish vessels. A second stratified sample of reef fish fishermen record discards by species. The data that we use in our analysis consists of the set of vessel operations that record both expenses and discards .

Our data are from January, 2005 through August, 2008. There are 1,753 trip-level observations with complete information on trip expenses and discards. Of these, 75 records included entries that we deemed to be outliers. Trips that recorded extreme costs per landed pound were deemed outliers; observations with costs less than \$0.04 per pound and in excess of \$2.50 per pound were dropped. Furthermore we removed fishing trip in subregion 12 which corresponds to the New Orleans estuary. Finally we deemed landings of more than 10,000 pounds of one particular species to be non-typical (the average landings of all species for vertical line gear is 1,854.61 pounds) .Remaining data includes 1,518 vertical line gear trips and 170 longline trips. The empirical results that follow are for vertical line gear.

Tractability requires that individual reef fish species be aggregated to form output groups. The four major species harvested include: h_1- red snapper; h_2- vermilion snapper; h_3- red grouper; and h_4- gag grouper. The remaining species were aggregated into output groups based on similarity in harvesting practices, e.g., fishing locations, depths, bait, and capture methods, used to in harvesting.[17] This resulted in three additional outputs: h_5- Deep water groupers and tilefishes; h_6- Coastal pelagics and sharks, and h_7- Other reef fish species.

We take as our spatial index, the coarse geographical region that yielded the bulk of the each trip's catch. The index takes the value of 1 on trips taken in the Florida Keys and 21 for trips taken in waters off the southern Texas coast. It should be emphasized that additional and finer-grained information on fishing location (e.g., latitude, longitude and fishing depth) if available could be incorporated into the model described above. Our data lists the date that the catch is landed at port. We specify a time index t which indicate the day of the year that landings are recorded, and an index y which is set equal to the cumulative days since January 1, 2005; y therefore ranges from 1 through 1,380. We impose the restriction that the seasonal effect on January 1 equal the effect on December 31 of each year. Both t and y are normalized to line on the unit interval.

[17]Harvested quantities within each output category are aggregated linearly. The aggregation procedure assumes that optimal input choices and aggregate output levels can be chosen independently of the mix of species within each output category. The harvest technology is thus assumed to exhibit weak output separability. Linear aggregation implies a constant rate of transformation among species within each output group. These assumptions are consistent with fishing practices as described to us by reef fish fishermen. Nonetheless, it should be noted that output aggregation could bias the results that follow.

4.4.2 Regulations

The Gulf of Mexico Fisheries Management Council is responsible for the management of Gulf reef fish. A host of regulations including vessel entry (fleet size) restrictions, gear and area restrictions, seasonal closures, per-trip catch limits and recently individual fishing quotas are used to limit the aggregate harvest of the commercial fleet. Possibly the most regulated species in the reef fish complex is red snapper. Prior to December 2007 red snapper was managed under controlled access regulations. Under this system an annual total allowable catch (TAC) was selected by managers and enforced with fishery closures and a per-trip *endorsement* program.[18] The endorsement program restricts landings of red snapper on each fishing trip, during red snapper openings. Vessel operators held either a class 1 permit to land 2,000 pounds per trip, a class 2 permit to land 200 pounds per-trip, or no permit at all. Vessels that do not own an endorsement permit are prohibited from landing red snapper at any time.

In an effort to spread the annual red snapper harvest more evenly throughout each year, red snapper landings were permitted during the first 10 days of each month. When the cumulative fleet harvest reached the annual TAC, the fishery was closed until the following year. The implications for fishing behavior during the controlled access management period (1/1/05-12/31/06) are summarized in the following table.[19]

Regulation	Opt. landings/discards	KT necess. cond.
1. $\bar{l}_i = 0$	$l_i^* = 0$, $d_i^* > 0$	$c_i^*(h^*, x) = 0$
2. $\bar{l}_i = 200\ (2,000)$	$l_i^* > 0$, $d_i^* = 0$	$\eta p_i - c_i^*(h^*, x) \geq 0$
3. $\bar{l}_i = 200\ (2,000)$	$l_i^* > 0$, $d_i^* > 0$	$c_i^*(h^*, x) = 0$

Beginning in January 2007 red snapper controlled access regulations were replaced with individual fishing quotas (IFQs). Under the IFQ program, vessel operators can legally land any quantity of red snapper as long as they possess quota to cover landings. The IFQ program was begun by issuing red snapper quota *gratis* to qualifying fishermen. The amount of quota

[18] The red snapper TAC was set at 4.65 million pounds in 2005 and 2006. Stock concerns led to reductions in the TAC in 2007, to 3.315 million pounds, and a further reduction in 2008, to 2.55 million pounds.

[19] A minimum size restriction of 15" total length was in place during 2005-06. The length restriction was reduced to 13" total length in 2007-08.

that was distributed was based on historical participation, i.e., history of red snapper landings during designated qualifying years. Therefore, vessels that held class 1 endorsement permits under the controlled access regime tended to receive larger shares of red snapper IFQ. The implications for fishing behavior during the IFQ management period (1/1/07-08/31/08) are summarized in the following table.

Regulation	Opt. landings/discards	KT necess. cond.
1. $\bar{l}_i = 0$	$l_i^* = 0$, $d_i^* > 0$	$c_i^*(h^*, x) = 0$
2. $\bar{l}_i = \infty$	$l_i^* > 0$, $d_i^* = 0$	$\eta p_i - c_i^*(h^*, x) \geq 0$

Grouper species are also heavily regulated. Red grouper is managed as part of a shallow water grouper complex, which includes Black, Gag, Red, Yellowfin, Scamp, Yellowmouth groupers, Rock Hind and Red Hind. The shallow water grouper fishery is closed when a red grouper TAC of 5.31 million pounds is reached, or when a TAC of 8.80 million pounds for all shallow water groupers is reached (the closure occurs at the first date either constraint is met). In addition, measures are used to protect fish during heightened spawning activity. The red and gag grouper fisheries are closed from February 15 through March 15 of each year. An aggregate trip limit of 6,000 pounds of shallow water and deep water groupers combined was introduced for the 2006 fishing season.

Deep water groupers and tilefishes, hereafter DWG, are also managed under controlled access regulations. Fishermen face a per-trip limit of 6,000 pounds and the fishery is closed when the annual TAC is reached. The commercial deepwater grouper TAC is currently set as 1.02 million pounds. The commercial tilefish TAC is currently set at 440,000 pounds. There are no size limits for deepwater grouper species or tilefish since these fish do not survive retrieval from the depths in which they are caught. The behavioral implications of regulations on groupers and other species are available from the authors upon request.

Variable description	Parm.	Median	Std. dev.	95% c.i.
Constant	β_0	-2.292	0.021	[-2.334, -2.253]
Fuel price	β_w	0.504	0.009	[0.488, 0.526]
Vessel length	β_K	1.119	0.015	[1.095, 1.156]
Sub-region	β_s	1.170	0.012	[1.146, 1.194]
Sub-region^2	β_{ss}	-0.080	0.019	[-0.116, -0.037]
Red snapper	β_1	0.109	0.004	[0.102, 0.116]
Verm. snapper	β_2	0.132	0.008	[0.120, 0.148]
Red grouper	β_3	0.251	0.007	[0.239, 0.265]
Gag grouper	β_4	0.249	0.012	[0.220, 0.269]
DWG/Tilefishes	β_5	0.231	0.010	[0.208, 0.245]
Coastal pelagic/sharks	β_6	0.269	0.011	[0.246, 0.291]
Other species	β_7	0.138	0.007	[0.126, 0.153]
Crew shares	η	0.546	0.005	[0.536, 0556]
Targ. cost (mean)	$\bar{\gamma}$	3.090	0.074	[2.953, 3.247]
Targ. cost. (var.)	σ_γ^2	4.686	0.603	[3.655, 6.029]

Table 4.1 Posterior parameter distribution. Table reports the median, standard deviation (Std. dev.) and 95% confidence intervals of the posterior parameter distribution.

4.5 Results

4.5.1 Posterior simulation results

Tables 4.1 report median values, standard deviations, and 95% confidence intervals of the posterior parameter distribution The individual parameter distributions are consistent with our assumptions for the structure of the harvest technology, and profit maximizing harvest choices under a costly targeting technology.

The results suggests that trip-level costs are increasing and concave in the fuel price; the posterior median value of β_w is 0.504, with 95% confidence interval [0.488, 0.526]. The posterior distribution for β_K has median value 1.119, and 95% confidence interval, [1.095, 1.156]. The result is consistent with trip-level costs that are increasing and convex in vessel length. At first glance this result seems counterintuitive. One would expect capital to be a normal input in production. However, larger boats tend to harvest more fish per trip, i.e., have a larger hold capacity, which can yield a return to scale. Moreover, larger vessels are better-able to fish in sever weather conditions. They can harvest more fish annually than smaller boats, and therefore incur lower average fixed operating costs.[20] This advantage is not reflected in the trip-level data. It is also possible that our proxy for capital services, which is a stock variable, does not fully reflect the capital services available for production on a fishing trip.

The posterior median for $\overline{\gamma}_v$ is 3.090 (c.i. [2.953, 3.247]), and the posterior median for σ_v^2 is 4.686 (c.i. [3.655, 6.029]). The results indicate considerable variation in targeting ability across skippers in our data, which is not uncommon in the analysis of harvesting performance (e.g., Squires and Kirkley, 1999).

The latent harvest share parameters π_i are generally well-identified.

Simulations that follow below suggest that the fitted values of φ_{st} are generally consistent with landing patterns and available biological information on stock abundance across space and time. Although it is tempting to view φ_{st} as an index of absolute stock abundance, we feel this interpretation is premature.

Finally the posterior median for η is 0.5461 which means that crews receive roughly 45% of the trip revenue. The posterior median is very close to the value from the log book data; the median crew share reported in the 2005-08 log book data is 44.21%.

Further interpretation of the results may be best-accomplished by examining their implications for fishing behavior. Space constraints do not permit a comprehensive demonstration. The following simulations highlight some of the more interesting aspects of fishing (targeting) behavior, and the influence of regulations in the reef fish fishery, that are implied by our estimation results.

4.5.2 Simulations

This section reports the results from several simulation exercises. In each simulation we draw with replacement a random sample of 1,000 vectors from the posterior parameter distribution.[21] For each draw, we use a numerical optimization routine to solve for the profit maximizing harvest and discard vectors for a representative vessel operation (equation (4.2)).

[20] A 1% increase in vessel length correlates with a 3% increase in harvest size per trip.
[21] We do not incorporate optimization error in our simulations.

We solve the optimization problem for each subregion of the reef fish fishery thus obtaining optimal landings and discards for (s,t) combinations, prices p, w and landing restrictions, $\bar{l}$. Variable profits, also quasi-rent to the vessel capital, captain and crew labor shares, marginal costs etc. are also calculated in our investigation and predictions of fishing behavior.

Our baseline simulation assumes a 40 foot vessel and prices equal to the mean of the sample data. We impose a per-trip landings of constraint of 5,000 pounds. The date chosen for the baseline simulation is the midpoint of the 2006 fishing season. Regulations in 2006 included red snapper landing limits under the endorsement program and closures for grouper species. Our baseline scenario assumes a 2,000 pound red snapper landings constraint. The effects of a grouper closure are considered separately.

Variable profits per trip vary around \$5,000-\$7,000 over much of the Gulf. Lowest variable profits are indicated in the far western regions of the fishery. Red snapper is a key species in the western region, and is the highest priced among the seven targeted species, averaging \$3.19 per pound landed. The 2,000 pound landings limit however constraints the profit potential for this species.[22] If we run the model without the 2,000 pound limit on red snapper landings, the variable profits flatten out at roughly \$10,000 per trip across all subregions of the fishery.

The model predicts that the 2,000 pound red snapper landings constraint binds in all subregions of the fishery. In the western and central subregions the remaining 3,000 pounds of landed fish is made up of vermilion snapper and gag grouper, with a smaller amount of Other Species landed in subregions 18-21. In eastern subregions a smaller amount of vermilion snapper is landed and no landings of Other species are recorded. Remaining landings are comprised largely of gag grouper and red grouper in subregions 3-7. Targeting of red snapper and gag grouper is explained by the relatively high dockside prices for these species, which are set a \$3.19 and \$3.10 per landed pound respectively in the baseline case. The remaining variation in targeting behavior is due to spatial variation in targeting costs as measured, as measured by φ_{st}. The fitted lowest-target-cost share for red snapper exceeds 0.70 in the far

[22]Fishing vessels are mobile and we would expect to see only small variation in per-trip profits across space. The higher returns in the eastern region do not reflect the impacts of periodic grouper closures. Moreover a vessel with a 200 pound endorsement permits, or no red snapper landings permit will have a different earning profile. Taking these considerations into accout, we can conclude that profit opportunities do not vary substantially with s..

western subregions of the fishery, and declines monotonically toward the eastern subregions. Interaction between the 2,000 pound red snapper landing limit and φ_{st} explains the decline in variable profits for $s > 14$.

The model predicts median red snapper discards that range from 200 pounds in subregion 16 to 550 pounds in subregion 20. Discarding red snapper occurs when *optimal* harvests exceed the 2,000 pound landing limit. Under the weak output disposibility technology, discarding avoids the targeting costs that would otherwise be required to harvest only what is landed. With fitted values of $\varphi_{i,st}$ in western subregions $s = 16 - 20$ well above 0.50, harvesting 2,000 pound of red snapper on a 5,000 pound trip requires costly targeting. The model suggesting discarding overages is preferred.

The model predicts fairly substantial discards of Other species, h_7 (as high as 1,500 pounds in subregions 1-4). These discards arise because of the per-trip landings constraint assumed in the baseline simulation. At 5,000 pounds total landings, estimated variable profit margins for landed species at roughly \$1.12 per pound, whereas marginal profits for Other species is less than \$1.

When we simulate harvest behavior without the 2,000 pound red snapper landings constraint optimal landings are comprised almost entirely of red snapper. Only in subregions 5-8 are positive landings of gag grouper indicated. Red snapper discards are zero in the absence of the red snapper landings constraint, although discards of Other species and vermilion snapper are indicated. It should be emphasized that the predicted discards arise due to the total trip landings constraint assumed in the baseline model.

Our second simulation examines seasonal effects on harvest behavior and variable trip profits. We solve for optimal harvests and discards on a trip that originates January 1, 2006. Prices are unchanged from the baseline levels, and the 2,000 pound limit on red snapper landings remains in place.

Economic and regulatory conditions are unchanged in the second simulation. The model predicts differences in the landings mix, discards, and profits due to the seasonal variation in the minimum-target-cost harvest vector φ_{st}. We also find that winter fishing earns slightly lower variable profits in the western subregions, but yields between 2-5% higher profits in the eastern subregions. We also find that optimal landings mix in the winter includes larger shares of vermilion snapper in the central subregions and larger shares of gag grouper throughout the Gulf.

Our empirical estimation reveals that $\varphi_{i,st}$ for red snapper and gag grouper exhibit summer troughs or winter peaks. Thus the harvest vector that minimizes targeting costs will be comprised of larger shares of red snapper and gag grouper during winter fishing. The model also predicts an increase in the *harvest* of red snapper. However, under the 2,000 pound landings limit, overages are discarded at sea. The model predicts that in the western subregions of the fishery, winter discards of red snapper are 200-700 pounds higher than during summer fishing.

In a third simulation we reduce the red snapper price by 25% below the baseline value (of \$3.19 per pound). Panel (c) reports the percentage change, decline, in variable profits across subregions. The results indicate variable profit declines in the range of 14%-18% in western subregions and 12%-13% in eastern subregions. The mix of landed species is unchanged in western subregions 13-21. This is explained by the importance of red snapper in the western Gulf. In the east however the model predicts that a 25% drop in the red snapper price has important implications for targeting behavior. Under the lower red snapper price, red snapper landings decline in subregions 1-12. Eastern Gulf fishermen land instead larger quantities of vermilion snapper, red grouper, and gag grouper. Our model predicts that the red snapper price decline does not significantly alter discarding behavior.

A fourth simulation considers the effects of a closure of the red and gag grouper fisheries. The results find that the closure policy causes reductions in variable profits vary widely across subregions. Losses are greatest, in excess of 10%, in subregions 4-9 which is considered to be the heart of the grouper fishery. Losses are smaller in the central region where shallow water groupers are a less important target species, and increase again in the western region where high-priced gag groupers comprise a important share of landings. The results indicate that when the red and gag grouper fisheries close, landings of vermilion snapper (h_2) and deep water groupers and tilefishes (h_5) increase. Not surprisingly, the model predicts positive discards of red grouper in subregions 5-7, i.e., when red grouper landings are prohibited fishermen can either incur added costs to avoid them or discard the red grouper intercepted by their gear.

The results reported above by no means exhaust the economic and regulatory impacts that can be examined by our model. We consider in a fifth simulation exercise the impact of an increase in the price of fuel. The annual average fuel price in our data rose from $2.27 in 2005 to $3.75 in 2008, and it is therefore reasonable to expect that fuel prices affected the reef fish targeting behavior in our data. The simulations find that a 40% fuel price increase reduced per-trip variable profits by 5%-10% relative to baseline levels. The model predicts that higher fuel prices impact targeting behavior. We find that the median targeting cost component, $\left[1 +_{i=1}^{m} \gamma_v \left(\theta_i - \varphi_{i,st}\right)^2\right]$ decline by 2%-5% depending on the subregion under the higher fuel price. Intuitively, targeting efforts will be dampened under higher fuel prices and the optimal harvest share will more closely mirror the minimum-target-cost vector φ_{st}. This is because adjusting the harvest mix in response to price differentials at the dock becomes more costly when the fuel price rises. Our simulations indicate, for example, that landings of gag are reduced by 200-300 pounds across the fishery. Landings of vermilion snapper increase primarily in the central subregions and landings of red grouper increase under in subregions 2-7. The model predicts, also rather intuitively, that at-sea discards decline under high fuel prices.

Recall that the empirical specification for φ_{st} includes a time index y to capture longer term trends in stocks conditions in the fishery. This allows us to examine longer term trends in targeting behavior. Simulations that varied y for example, from 2005 through 2008, indicated only minor changes in variable profits and targeting behavior. The results are not reported here.

We construct a final simulation to examine the changes in fishing behavior that accompanied a switch from controlled access to individual transferable quotas (ITQs) for red snapper. To represent this policy switch we introduce a quota user cost which we assume arbitrarily to be equal to 50% of the baseline red snapper price, and drop the 2,000 pound landing constraint. Under ITQs trip limits on landings are no longer required; landings are restricted only at the seasonal level by the aggregate ITQ holdings of the vessel operation. We evaluate optimal harvests and discards for a mid 2007 season trip, which was the first year of the red snapper ITQ program.

First, the results indicate a reduction in trip variable profits ranging from 15% in eastern subregions and increasing to 33% in western subregions.[23] The reduction in variable profits or capital quasi rents conforms with theoretical predictions, that property rights-based management programs provide incentives to reduce oversized fishing fleets. An important results for managers, however relates to the stark variability in losses across regions. Because targeting costs vary across subregions, substitute target species and red snapper fishing costs do as well. Our model suggests that introducing ITQ for a single species in a multiple-species fishery can significantly alter harvests and discards of species managed under the status quo. In particular, our model predicts that red snapper landings increase above the 2,000 pounds in the far western subregions. Vermilion snapper landings also increase in subregions 10-17 where these two species tend to be harvest complements. The addition of the red snapper quota rental substantially lowers the residual price for fishermen at the dock. Our model predicts that eastern landings of red snapper fall to zero when a quota rental is introduced; optimal landings instead include substantially higher shares of vermilion snapper, gag grouper and red grouper.

A less anticipated impact on fishing behavior is a predicted increase in red snapper discards. Results indicate positive red snapper discards in subregions 7-16, ranging from 150 pounds per trip to over 1,000 pounds per trip (subregions 13 and 14). This result is due to the 5,000 pound per-trip landings constraint. At a substantially reduced red snapper price and a 5,000 pound trip limit on landings, the marginal profit from landing red snapper falls below marginal profits from landing other species such as vermilion snapper and red and gag groupers.

[23]Looses in variable profits are offset by increases in resource rents generated under the red snapper ITQ program. These rents would be determined as the quota rental times the total red snapper landings.

4.6 Conclusions

We have introduces a new approach for studying spatial-temporal fishing behavior in marine fisheries. We estimate a structural behavioral model that provides a direct link from the *in situ* fish stock, prices and species-specific regulations, to outcomes of interest to managers, e.g., species-specific harvests, discards and fishing profits. A parametric cost function and Kuhn Tucker necessary conditions for profit maximizing targeting of multiple fish species under landings restrictions is specified for estimation. Markov Chain Monte Carlo methods are used to simulate the posterior likelihood function. We estimate a latent, *lowest-target-cost* harvest share vector that summarizes the costly targeting technology and corresponding profit opportunities for fishermen across space and time. The fitted model is used to predict the effects of changes in economic conditions and regulations on spatial and temporal landings, discards, and fishing profits in the Gulf of Mexico reef fish fishery.

Our results demonstrate complex interactions between the economic and regulatory environment and the multiple-species harvesting behavior of Gulf reef fish fishermen. Not surprisingly, we find that per-trip landings limits used to control aggregate fishing mortality redirect fishing effort toward unregulated species, in pattern that vary spatially with stock conditions. We are also able to investigate the effects of model fundamentals on the incentives to discard fish at sea.

Several policy lessons emerge from our analysis of the Gulf reef fish fishery. For example, replacing controlled access management with individual fishing quotas for a single species, is likely to redirect effort toward species without a quota rental, and may enhance incentives to discard fish at sea. We also find, not surprisingly, that closures for individual species cause fishermen to substitute toward unregulated species, and can enhance incentives to discard fish. Less obvious findings relate to the impact of increased fuel prices on targeting and discard behavior. Our model predicts that when the price of fuel rises, Gulf reef fish fishermen may be inclined to target higher priced species, and more willing to land a mix of species that moderates targeting costs. On the flip side, targeting is enhanced and at-sea discards will increase when fuel prices decline. Overall the results demonstrate the need to consider behavioral responses and policy design inclusive of the complete biological, economic and regulatory environment of marine fisheries.

An important attribute of our model is that optimal responses of fishermen to varying economic and other regulatory conditions is incorporated explicitly. Our results demonstrate clearly the benefits of a structural approach for policy analysis. Moreover, because we are able to link fishing behavior directly to stock conditions, prices and regulations, the model is ideally suited to investigate *ex ante* impact of alternative forms of regulations. Methods based on the discrete choice RUM framework require a second layer model to complete the link from fundamentals to trip-level behavior. Our approach avoids discretizing the fishing ground and/or the choice set of fishing inputs and outputs; our approach provides a rich framework to characterize fishing behavior at any spatial or temporal scale. Taken together these attributes suggest that our model can be a powerful tool to improve the design of fisheries management policies.

For example, our model can guide the design of fishery closure policies, property rights-based management, marine reserves, etc. Designing a system of marine reserves requires knowledge of trade-offs between ecological preservation across a spatially heterogeneous fishing ground and pursuit of economic rents. Our model measures directly, the short term cost, or foregone profits of closing subregions of a fishery. A useful extension of our model would link our costly targeting technology, and our lowest-target-cost share vector, to measures of absolute stock abundance. This would allow a fully dynamic analysis of spatial behavior and spatial management policies. Evaluating changes in stock abundance in areas surrounding marine protected areas, and stock effects due to large scale redistribution of fishing effort across space and time are examples.

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CHAPTER 5. GENERAL CONCLUSION

These three essays by considering the management of fisheries, the trade of genetically modified and the financing of agricultural producers show how wide are the fields of application of microeconomics and how useful is its intellectual framework in providing insights to applied questions. Furthermore this thesis makes several contributions to the literature.

The first essay shows how the capacity of enforcing intellectual property rights by a country establishes its adoption and labeling regime of the products of the biotechnology. This result to the best of our knowledge is new and provides relevant insights on the regulatory responses to the genetically modified technology by developing countries.

The second essay demonstrates that by bundling several tasks within its procurement organization the supermarket reduces agency rent. This reduction in agency rent is conducive of credit extension and thereby a larger participation in the marketing channel. This result is also to the best of our knowledge new and contributes to the literature on microfinance.

Finally the framework developed in the last essay by combining the economic and ecologic approaches in the analysis of fishermen behaviors and fish stocks dynamic should contribute to the improvement of the fishery management.

APPENDIX A. ADDITIONAL MATERIAL

A.1 Prior specifications

With the exception of the targeting skill parameter, all priors are assumed to be diffused. A hierarchical prior captures heterogeneity in fishing skill. We assume

$$\gamma_v \sim N\left(\bar{\gamma}, \sigma_\gamma^2\right). \tag{A.1}$$

Following standard methods (e.g., Chib and Carlin, 1999) we use conventional conjugate priors for the hyperparameters of this distribution, i.e.,

$$\sigma_\gamma^2 \sim IG\left(2.5, 3\right), \tag{A.2}$$

$$\bar{\gamma} \sim N\left(0, 1000\right); \tag{A.3}$$

in the above $IG(.)$ and $N(.)$ denote the inverse gamma and normal distribution, respectively.

A.1.1 Random Walk M-H Algorithm

Here we simply present the Random Walk Metropolis Hastings (RWMH) algorithm. For further details on the Metropolis-Hastings (M-H) algorithm we refer the reader to (Chib, and Greenberg, 1995). The M-H algorithm is similar in spirit to acceptance/rejection sampling and consists in three steps:

1. At iteration ω, sample a candidate value for the parameters from a candidate density

$$q_\omega^* \sim \delta\left(q|q_{\omega-1}\right) \tag{A.4}$$

2. Draw a random number u such that

$$u \sim U(0,1) \tag{A.5}$$

3. Accept or reject the candidate based on the following decision rule. Let

$$a = \frac{\phi(q_\omega^*|.)\,\delta(q_{\omega-1}|q_\omega^*)}{\phi(q_{\omega-1}|.)\,\delta(q_\omega^*|q_{\omega-1})} \tag{A.6}$$

where $\phi(q|.)$ denotes the posterior distribution of q according to the data. Then if $u \leq a$, set $q_\omega = q_\omega^*$ otherwise $q_\omega = q_{\omega-1}$.

In the RWMH algorithm the candidate density is normal so that

$$q_\omega^* \sim N\left(q_{\omega-1}, \sigma_q^2\right). \tag{A.7}$$

In the above, σ_q^2 is the variance os spread of the normal distribution. The main idea behind the M-H algorithm is to replicate the stationary property of the Markov chain. Indeed a can be interpreted as the "jump" probability from one candidate to the next. This probability is pending on the value of the spread. The art of the RWMH algorithm dwells in setting the value of this spread. We follow the recommendation of Gelman and Gilks (1995) and specify the spreads of our candidate generating density so that the acceptance rate is close to 50 percent for single valued parameters and between 25 and 50 percent for multi-valued parameters.

A.1.2 Estimation algorithm

We use a Gibbs sampler to simulate draws from the posterior of the joint posterior density. The following algorithm describes the procedure.

Using the Gibbs sampler we repeatedly cycle through each conditional density, drawing from each one in turn. When the number of cycles grows large, the draws converge in distribution to that of the complete joint posterior (Gelfand and Smith, 1990). Our Gibbs sampler consists of seven steps or "blocks".

Step 1: $\beta|\Gamma_{-\beta}, Z$ As this posterior conditional is of unknown form we use the RWMH algorithm explained above. For further reference $\Gamma_{-\beta}$ indicates the entire set of parameters less the parameter β.

Step 2: $\Sigma | \Gamma_{-\Sigma}, Z$.