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The Impact Of Risk On Contract Structure In A Principal-agent Model: An Application To The Alberta Sugar Beet Industry

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THE IMPACT OF RISK ON CONTRACT STRUCTURE IN A PRINCIPAL-AGENT MODEL:

AN APPLICATION TO THE ALBERTA SUGAR BEET INDUSTRY

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ABSTRACT

The paper models a particular share contract (that between the refiner and growers of sugar beets in southern Alberta) within the context of the principal-agent paradigm. That is, a principal (the refiner) chooses contractual terms so as to motivate the agents (the growers) to apply that amount of variable input (fertilizer) which leaves the principal's expected utility being maximized. The central issue considered is how specific contractual terms are related to the attitudes toward risk of the individuals. In carrying through with this exercise, we examine the actual contract in order to restrict the contracts considered to a subset of those which are theoretically possible. For instance, a share contract may involve monitoring by the principal but since the actual sugar beet contract does not, we assume that the costs of monitoring outweigh the benefits; instead of trying to characterize the forces which give rise to a contract which does not involve monitoring.

Once the theoretical analysis is completed, a simulation experiment then shows how the terms of the contract and input use respond to changes in the attitudes toward risk of principal and the agents, along with adjustments in the characteristics of their subjective probability distributions.

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The work is dedicated to my mother and father, and to Donna and Sharon; my sisters. Were it not for their encouragement, this study would never have been completed.

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CHAPTER I

OUTLINE

I.1. Introduction

This thesis investigates the contractual arrangement that exists between the refiner and growers of sugar beets in western Canada. Our method is to construct a stochastic model, the analysis of which will allow us to relate some of the characteristics of the contract and input decisions of growers, to both the individuals' differing perceptions of the likelihood of future events, and their differing attitudes toward risk. This exercise provides some further insight into the impact of risk on such problems.

Prior to the actual seeding of the beets in the early spring, the refiner and the individual farmers sign a contract. Of its provisions, two are of especial concern to us and help to determine the model used here. First, there is the payment scheme. Whereas for some crops (tomatoes for instance), the growers receive a guaranteed price for their product, the beet growers receive no such guarantee. Instead, the refiner extracts the sugar from the beets then sells it, under the contract the costs of refining are then subtracted from the gross sales revenue, and the refiner and the farmers share what remains: those costs being reported by the refiner, and checked by an independent auditor. The farmers' share will be between 58% and 63%; it being determined by the average price (net of refining costs) received for the sugar. So long as the net price is not greater/less than $138.00/$154.00 per tonne, the farmers' share will be constant at 58%/63%. In the intermediate range of prices, on the other hand, their share will be an increasing linear function of the net price. The second important provision of the agreement is a specification of the individual farmer's contracted acreage.

After the contract is signed, the beets are seeded. Thereafter, and several times during the growing season, various chemicals - along with irrigation water in southern Alberta - have to be applied to the crop: without loss of generality, all these factors of production are represented by fertilizer in our theoretical framework. Moreover, the choice of pattern of utilization for all variable inputs is left to the farmer. That is, nowhere in the sugar beet contract is there a stipulation regarding the duties of the individual farmer. This should not be surprising because while the refiner can monitor the farmer's output, monitoring the farmer's effort, or input use more generally, will be costly. Since we do not observe contracts with inputs monitored by the refiner, these costs are assumed to be larger than the benefits and we model input decisions as taken by the farmer to be his decision.

The market structure in the beet processing industry in western Canada is one of monopsony. There are approximately seven hundred farmers involved in the primary production of sugar beets, but only one processor. Given this situation, and the fact that 'real' negotiations regarding the payment scheme and acreage allottments do not take place between the refiner and the Sugar Beet Grower's Associations, we assume that the processor offers contract terms, rather than having them determined bilaterally. But the processor is subject to a constraint. There are other cash crops - potatoes and corn, for instance - which offer high returns to their growers. In order to induce farmers to grow beets, the terms offered in the contract must be competitive with those offered elsewhere. It is for this reason that the refiner's monopsony power is quite limited: it is only by choosing the terms of the contract so as to motivate the farmers to apply the optimal amount of fertilizer - in the sense that the refiner's expected welfare is being maximized - that his monopsony power comes into play.

From the discussion of the previous two paragraphs, we conclude that both the refiner and the farmers have variables they unilaterally control. In this thesis we will consider how these two decisions interact to yield an equilibrium. When formalizing their relationship in subsequent chapters, we will do so within the principal-agent paradigm, with the refiner acting as the principal and the farmer as the agent.

I.2. Methodology

In this section we present a brief description of the model that is employed in Chapters IV and V. Let us define:

P = price per tonne of refined sugar net of delivery charges,

r = cost per pound of fertilizer,

θ = proportion of the profits from the sale of refined sugar that is received by the refiner (with the rest going to the farmers),

B = revenue transfer from the refiner to the farmers (as a group),

$\tilde{T}$ = the normal return accruing to the farmer as manager and as a laborer on his own farm,

N = number of identical farmers,

A = number of acres seeded into beets by the individual farmer,

a = cost per acre of using land in the production of sugar beets,

F = amount of fertilizer to be applied per acre,

$g(F)$ = output per acre as a function of fertilizer usage,

Q = output of the individual farmer,

$= Ag(F)$,

$C(NQ)$ = cost of processing the beets into refined sugar,

Y_R = the refiner's profit,

$= \theta(NPAg(F) - C(NAg(F))) + B$,

Y_T = the individual farmer's income,

$= \tilde{T} + (1 - \theta)(NPAg(F) - C(NAg(F)))/N - B/N - rAF - aA$,

$U_R(.)$ = refiner's Von Neumann - Morgenstern utility function, and

$U_T(.)$ = individual farmer's Von Neumann - Morgenstern utility function.

Step 1: The Farmer's Problem

Given the nature of the payment scheme - θ and B - and contracted acreage, the farmer will choose that level of fertilizer use so as to maximize his expected utility of income. That is

$$\max_{(F)} E(U_T(Y_T))$$

The solution to the maximization procedure allows us to recognize how changes in θ, B, and A - along with all the exogenous variables - would result in an adjustment in fertilizer use; that is $F=F(\theta,B,A;a,r,\ldots)$.

Step 2: The Refiner's Problem

In order for the farmer to be induced to enter into the contractual arrangement, he must be adequately reimbursed. We account for this formally by assuming that the payment scheme must guarantee him a minimum acceptable level of expected utility. Taking the constraint into account, the refiner will then choose θ, B, and A so as to maximize his own expected utility of profit. Let us recall that our refiner is fully cognizant of the farmer's decision making process, and therefore can take advantage of that knowledge when setting the terms of the contract. It is not necessary, however, that the refiner actually be able to monitor the farmer's application of fertilizer. In a sense, the refiner simply puts himself in the farmer's shoes in predicting how the farmer will react to a given contract: this allows him to specify $F=F(\theta,B,A;a,r,\ldots)$. Thus, the refiner's problem may be written as

$$\max_{(\theta,B,A,K)} V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

where $\bar{U}_T$ = the minimum acceptable level of utility required by the farmer,

K = the Lagrange multiplier.

When setting the terms of the contract, the refiner will base his decision on his own evaluation of the price uncertainty. Similarly, the individual farmer will make use of his own subjective perception of the riskiness when determining fertilizer use. In general, there is no need for their subjective probability distributions to be identical - especially in the short run. We should also point out that a series of adjustments are not required if a full equilibrium is to be attained. Prior to choosing θ, B, and A, the refiner knows exactly how the farmers will react to the choice. Because of this, an adjustment process will not be required since the initial values for θ, B, and A that the farmer will base his decision on, and the equilibrium values, are identical.

In this thesis we try to gain some insight into the relationship which exists between the attitudes toward risk of the refiner and farmers, on the one hand, and the characteristics of the contract and fertilizer use, on the other. Not surprisingly, if the farmers are 'more' averse to risk than the refiner, θ and B will be set so that the farmer's income is relatively non-risky. A second important factor follows from the refiner's prediction of the farmer's behavior. Given this knowledge, the refiner will set the terms of the contract so as to motivate the farmers to apply the optimal amount of fertilizer - optimal in the sense that the refiner's expected utility is maximized, and subject to the fact that the refiner does not observe (monitor) the use of fertilizer.

I.3. <u>Layout of the Thesis</u>

In Chapter II we will review the sugar refining industry in Canada. Our attention will be focused on the determination of the terms of purchase for imported sugar, and the linkage, if any, that exists between the prices of domestic beet, and imported sugar.

Chapter III is devoted to a survey of the literature on share contracts. Beginning with the work of Marshall (1966), we shall recognize that his analysis had a major problem associated with it. While several researchers recognized this, it was Cheung (1969) who introduced the crucial improvement. As we shall report, much of the subsequent work on sharecontracting made use of an extended Cheung-type framework. Recently, similar issues have been raised in the principal-agent literature, and we shall recognize the importance of these (researcher's) contributions.

The pivotal chapter of this thesis is IV because it is here that we will construct a stochastic model of the sugar beet industry. Once this is done, the equilibrium will be characterized.

As will become apparent in Chapter IV, our theoretical framework is such that certain key results are not obtainable in the general setting chosen. Thus in Chapter V, and in order to gain greater insight into the impact of risk on certain contract parameters and input decisions, we will report the results of a computer simulation of the system.

And finally, the main results of this thesis will be summarized, and some suggestions for further research will be made, in Chapter VI.

CHAPTER II

THE INSTITUTIONAL FRAMEWORK OF THE SUGAR BEET INDUSTRY

II.1. Introduction[1]

Over the last twenty years, the per capita consumption of sugar in Canada has been remarkably stable - averaging out at approximately one hundred pounds per year. A relatively small proportion of this sugar - 10% - is refined from domestically produced beets. These beets are currently[2] grown in three areas of the country; in southern Alberta, southern Manitoba, and near St. Hilaire in Quebec. The remainder of the sugar is refined from imported raw cane sugar. Canadian refiners purchase raw cane primarily from Australia, Mauritius, and South Africa.

In this chapter, we will examine the characteristics of the sugar refining industry in Canada. Section 2 will be concerned with the oligopolistic nature of the industry, it's pricing practices, and sources of supply. The focus of Section 3 will be somewhat narrower in that we concentrate on the internal structure of the beet sugar industry; whereas in Section 4 a procedure for modelling it is discussed. Building upon this discussion, in later chapters a formal model will be developed which is based upon the the characteristics of the sugar beet contract. Finally, some concluding remarks are made in Section 5.

II.2. The Structure of the Sugar Industry in Canada

The sugar refining industry in Canada is an oligopoly, with seven firms controlling the ten refineries. Of the ten, only three refine sugar from domestically produced sugar beets. The remaining seven use imported raw cane sugar as their primary input.[3]

Table II-A

Firms of the Canadian Sugar Refining Industry

Operating Company or Division	Plant Locations	Plant Capacities (lbs./day)	Parent Organization
Atlantic Sugar	St. John, N.B.	2,400,000	Jannock Corp. Ltd.
The British Columbia Sugar Refining Co., Ltd.	Vancouver, B.C.	2,000,000	B.C. Sugar Refinery, Ltd.
Canadian Sugar Factories Ltd.	Taber, Alberta	1,000,000	B.C. Sugar Refinery, Ltd.
The Manitoba Sugar Co. Ltd.	Fort Garry, Manitoba	700,000	B.C. Sugar Refinery, Ltd.
Cartier Sugar Ltd.	Montreal, Quebec	500,000	Steinberg's Ltd.
Quebec Sugar Refinery	St. Hilaire, Quebec	350,000	Government of Quebec
Redpath Sugars Ltd.	Montreal, Que. & Toronto, Ont.	2,500,000 1,800,000	Redpath Industries Ltd.
St. Lawrence Sugar	Montreal, Quebec	1,900,000	Sucronel Ltd.
Westcane Sugar Ltd.	Oshawa, Ont.	900,000	George Weston Ltd.

Source: Food Prices Review Board (1975)

While only 10% of the sugar consumed in Canada is obtained from domestic sources, nevertheless, the beet sugar industry is still very important. For instance, the sugar market in Canada is highly regionalized. In fact:

(a) The eastern Canadian market - those provinces east of Manitoba -

is served by refineries in Ontario, Quebec, and New Brunswick. Of these refineries, only one - the refinery at St. Hilaire - refines sugar from beets.

(b) Demand for sugar in western Canada is satisfied by the two beet sugar refineries, and the single cane sugar refinery.

The beet industry is also important to the producing regions. For the approximately 2500 farms on which they are grown, sugar beets are a substantial source of farm income; for these farms, the gross farm income from sugar beets is larger than that from any other field crop.[4]

The seven refineries that produce sugar from raw cane purchase their primary input on the international open market; a market which is segmented into two parts. First, there is the raw sugar that is traded under bilateral or multilateral preferential agreements. For instance, most of Cuba's sugar production is purchased by China and the U.S.S.R. in this manner. The other two most important trading arrangements have been the Commonwealth Sugar Agreement, and the U.S. Sugar Act. Under the former, Britain agreed to assign 'negotiated price quotas' to various sugar exporting members of the Commonwealth: essentially Britain was guaranteeing the purchase of a certain amount of raw cane at a fixed, premium, price. With Britain's entry into the European Economic Community, this agreement lapsed, but it was replaced with one between the E.E.C. and the Commonwealth sugar exporting countries which had the same effect.

While the goal of the United States' sugar policy[5] was also to achieve stable prices and supplies, this was accomplished in a somewhat different manner. Under the U.S. Sugar Act of 1934, on a yearly basis, the Secretary of Agriculture determined the amount of sugar required in the U.S. Once this had been done, then production quotas were allocated among domestic and foreign suppliers. In past years, approximately 40% of U.S. sugar requirements had been met, in this manner, by 32 foreign countries. Thus in comparing the Commonwealth Sugar Agreement and the U.S. Sugar Act, we find that, under both of them, a quota scheme was used. But here the similarity ends, for while the former included a negotiated price, the latter did not. It was through the use of supply restrictions that prices were kept artificially high in the United States.

As of 1971, approximately two-thirds of the sugar being traded is covered by preferential agreements, with the rest being traded on the 'free' market. This market is "comprised of all international transactions outside the preferential agreements, is a residual market, serving ... as an important market for raw cane exporters which have only limited access to preferential markets."[6] Canadian refiners purchase raw cane on the free market.

Because it is a residual market, fluctuations in the supply of sugar can have a dramatic impact on the free market price. For instance, the price per long ton[7] of sugar rose from $42 in the 1960's to $111 in 1971, and $239 in 1973. Recognizing the inherent instability of the free market, the trading nations have negotiated a series of International Sugar Agreements (I.S.A.), the first one having come into effect in May of 1931, and the recent one in January of 1979.[8] The recent agreements have several objectives, the most important ones being:

"(a) to raise the level of international trade in sugar, particularly in order to increase the export earnings of developing exporting countries;

(b) to maintain a stable price for sugar which will be reasonably remunerative to producers, but which will not encourage further expansion of production in developed countries;

(c) to provide adequate supplies of sugar to meet the requirements of importing countries at fair and reasonable prices; and

(d) to provide for adequate participation in and growing access to the markets of the developed countries for sugar from developing countries."[9]

These goals were to be achieved through the use of a complicated scheme in which the sales quota of an individual exporting country was positively related to the free market price of raw sugar. If the price level remained within certain limits then the importing nations, as a group, were limited in the amount of sugar that they could purchase from non-I.S.A.-member exporters. If the price level fell far enough then a complete restriction on purchases from non-member exporters was imposed. Conversely, if the price exceeded a certain level, then all quota restrictions were suspended. Finally, if the free market price rose above a fixed maximum, then "exporters agreed to supply their traditional importers with their normal requirements."[10,11] From the above discussion, it follows that, as with the U.S. Sugar Act, supply restrictions are being used to control the price of raw sugar. This policy has turned out to be fairly successful in reducing the inherent instability of the free market.

The behavior that we find in the international sugar market represents a particularly good example of a risk-pooling arrangement. Many of the countries that export raw sugar under preferential agreements also sell part of their output on the free market. In a sense then, they have both 'regular' and 'casual' customers.[12] A preferential agreement represents a mechanism by which the two parties can 'pool' the risk associated with fluctuations, for instance, in price. By entering into the arrangement, the exporting countries and their regular customers are 'insuring' one another against the price adjustments that occur in the free market. There is a problem, however, with this scheme. At any point in time, "one of the parties will find that his actual outcome would be better if he were not bound by these arrangements."[13] The reason for this is quite simple. If the free market price exceeds the price under the preferential agreement, the the exporter would be better off if he were not bound by it. Hence, for risk-pooling arrangements to 'work' the two parties must be willing to accept this sort of price differential.

Even though Canada is a large purchaser of free market sugar, the available evidence suggests that the Canadian refiners are price takers: the 'price' being determined as follows. Each day a committee of sugar brokers in London, England, examine transactions in spot sugar and "bona fide offers of spot sugar that may not necessarily have resulted in completed transactions"[14] in order to determine that day's 'typical' price for raw cane C.I.F. London.[15] This price is referred to as the London Daily Price (L.D.P.). It will be influenced both by freight rates, and competitive forces in the free market. Table II-B shows how the L.D.P. represents the base for determining the delivered price of the raw cane to the Canadian refiners.

Table II-B

The Delivered Price of Raw Cane At Montreal (1971)

London Daily Price, C.I.F. London	£45-0-0 per long ton
Freight cost Caribbean to U.K.	£4-10-0 per long ton
Deduct 30% of Caribbean-U.K. freight from L.D.P.	£1-7-0 per long ton
Price, C.I.F. Montreal, exclusive of preferential premium	£43-24-0 per long ton
Price in Canadian funds, converted at $2.42 Can. to the U.K. £	$4.71 per 100 pounds
Add $0.75 (preferential premium) to give C.I.F. price at Montreal	$5.46 per 100 pounds
Add B.P. duty of $0.28712 to give C.I.F. price at Montreal, including duty	$5.75 per 100 pounds

Source: Tariff Board Report No. 146 (1971).

As is indicated above, the price of raw cane C.I.F. Montreal is determined by several factors, the most important one being the L.D.P. The Canadian refiners take the L.D.P. as given, then make an adjustment to account for the fact that it costs approximately 50% more to ship sugar to London, rather than to Montreal from the Caribbean. On top of this, there is added a preferential premium of $0.75 per one hundred pounds of raw cane, which is paid to suppliers which are subject to the British Preferential tariff. The premium can be thought of as having two components. First, since the Caribbean is the world basing point, exporting nations in the Pacific, such as Australia and South Africa, would be forced to absorb freight in order to be competitive in the Canadian market. But they could, and would, avoid this additional freight by selling to the Japanese, for instance. Hence, the Canadian refiners are forced to pay the additional freight charges if they want to obtain supplies of raw cane: the preferential premium is used to accomplish this. The second component of the preferential premium is negotiable, in the sense that it reflects the bargaining positions of the two parties. For instance, if the Canadian refiners are in a relatively strong position, they will be able to force down the preferential premium and therefore the price of raw cane that they purchase, i.e., perhaps the statement made previously regarding the price taking behavior of Canadian refiners was a little too strong since the existence of a negotiated premium will give Canadian refiners some influence over the landed price of raw cane. The final factor that is important in determining the price of raw cane C.I.F. Montreal is the Canadian tariff rate.

Over 90% of the raw cane imported into Canada is obtained from countries that are subject to the British Preferential (B.P.) tariff, with the remainder being obtained from Most Favored Nation (M.F.N.) countries. Since 1973, B.P. sugar of less than 99.5^{o} of polarization has entered Canada free, while M.F.N. tariff sugar has been subject to a tariff of approximately $1.00 per one hundred pounds.[16] Given this divergence in tariff rates, it is somewhat surprising that any M.F.N. raw cane is purchased. The reason can be traced to a drawback of duty on products which contain refined sugar; which was, itself, originally imported as raw cane. In effect, the government is returning the tariff revenue that was collected, but since the preferential premium will not be rebated by B.P. countries - for export purposes - M.F.N. sugar becomes cheaper. Clearly, however, for raw cane being consumed in Canada, B.P. sugar remains cheaper and it will dominate our domestic market.

Once the raw cane has landed in Canada, it is stored then converted into refined sugar as required. The industry prices it's product on a mark-up basis - a refining margin that covers costs and profits is added to the landed price of raw cane. Table II-C shows how St. Lawrence Sugar determines the price for refined sugar.

Table II-C

The Pricing of Refined Sugar

L.D.P.		£34-0-0 per long ton
L.D.P. converted to Canadian currency at $2.5749 to the U.K. £		$87.546 per long ton
		dollars per hundredweight
L.D.P.		$3.908
Cost of raw sugar C.I.F. Montreal, including pref. prem. and B.P. duty		$4.927
Cost of raw sugar stored in warehouse per hundredweight of raw sugar (Includes discharge and handling costs $0.060)		$4.987
Adjust cost of raw to allow for yield of 100 lbs. refined from 103.5 lbs. raw		$5.162
List price of refined sugar, Montreal	$8.250	
Deduct 2% discount for payment within 15 days	$0.165	
Discounted list price of refined sugar, Montreal		$8.085
Refiner's margin ($8.085-$5.162)		$2.923

Source: Tariff Board Report No. 146 (1971).

The one question that is not addressed in Table II-C is the method by which St. Lawrence arrived at a refiner's margin of $2.923 per hundredweight. As was noted earlier, the Canadian sugar refining industry is an oligopoly, with seven firms controlling the ten refineries. In eastern Canada, Redpath has the greatest plant capacity, and "is the acknowledged price leader with the other refiners normally matching Redpath's price changes with an identical change of their own on the same day."[17] By accepting Redpath's price leadership, the other refiners are having their refining margins determined externally. Implicitly, they are assuming that Redpath's "refining margin will remain constant in the short run and they can accept this margin as the bounds within which they must control costs and operate to make a profit."[18]

The market structure outlined above also gives us one reason as to why the sugar refining industry has been highly profitable in Canada. Through collusive behavior, the firms have been able to keep prices and profits quite high. The cane refining industry also receives a significant degree of protection from tariffs and transportation charges. With respect to the former, the tariff rate does give an indication of the protection received by the refiners, but a more useful measure is the effective rate of protection. It is a measure of the protection being accorded the "value that is added by Canadian refiners in converting raw cane sugar into refined sugar .....".[19] It may be shown that the effective rate of protection on a final product is positively related to its tariff rate, and inversely related to the tariff rates on any inputs used in its production. Murti (1972) found that the effective rate of tariff protection on the production of refined sugar exceeded the nominal rate by a factor of two: using the pre-1973 tariff structure, she calculated the effective rate to be 28.68%, while the nominal rate was 15.6%. Since freight rates are higher for refined than for raw sugar, the industry also enjoys natural protection from this source. Using an analysis which is analogous to that outlined above, Murti found an effective rate of natural protection of 49.98%. Bringing these two arguments together, the nominal tariff rate was only 15.6%, while the overall rate of effective protection was 77.66%. In 1973, the Canadian government followed the recommendations of the Tariff Board and altered the tariffs on both raw and refined sugar. The changes involved the elimination of the B.P. tariff and the reduction in the M.F.N. tariff rate on raw cane, but no real change in the B.P. tariff rate on refined sugar. That is, the tariff rate on the final product didn't change, while the tariff rate on an input fell. Ceteris paribus, the effective rate of protection must have increased, and the protection now received by the cane refining industry is even greater than was previously thought.[20] Given these results (along with those on the sugar refining industries market structure), it is not surprising that the industry is highly profitable. Two obvious questions to ask at this point are the following: have any firms recently entered the Canadian sugar refining industry, and have any of the existing firms expanded their capacities? The answer to the first question is a qualified yes. Cartier Sugar was established in 1963, and Westcane Sugar in 1974; no firms have entered since 1974. The primary reason for recent non-entry is straightforward. In the past the existing firms have tried to prevent potential entrants from obtaining supplies of raw cane in order to keep them out of the industry. Also since there exists excess refining capacity in Canada, none of the existing firms have recently added to their capacities.

Once Redpath - the largest firm - sets the price list and the other firms accept it, the refined sugar is sold via a basing-point pricing arrangement. In eastern Canada there are three basing points: Montreal, Toronto, and St. John, New Brunswick. The natural territory for the St. John basing point extends westward to Riviere-du-Loup; for the Montreal basing point from Riviere-du-Loup to Peterborough; and any point west of Peterborough but east of the Manitoba-Ontario border for Toronto. Outside of these regions, the refiners are forced to absorb freight. The adoption of basing-point pricing represents a mechanism whereby the refiners can maintain their collusive front and high profits. The reason being that "common adherence to basing point formulas in effect eliminates discretion and uncertainty, and if each firm plays the game and sticks to the formulas, price competition is avoided."[21]

In western Canada, one company - B.C. Sugar Refinery, Ltd. - controls the three refineries. As with the eastern Canadian refineries, the sugar refined from imported raw cane has it's price based on the L.D.P. - adjusted for the variables mentioned previously. On the other hand, refined beet sugar is not priced on the basis of "production costs or refinery margins involved in ... "[22] it's production. Instead, refined beet sugar is priced on the basis of the price of refined cane sugar F.O.B. Vancouver plus freight to any given centre. Once again, we find that basing-point pricing is used in the marketing of refined sugar, with Vancouver being the only basing point in western Canada. Let us recall that under basing-point pricing, the delivered price of a product equals the price at the nearest basing point - usually, but not necessarily, a production centre - plus freight charges to the destination. It follows that the price received by B.C. Sugar for refined beet sugar will be influenced by the location of the customer. For instance, if the beet sugar produced in Taber is sold there, the price that the customers are charged will include freight charges as if the sugar was shipped from Vancouver. Because of this B.C. Sugar earns excessive profits by charging for 'phantom freight'. On the other hand, suppose that beet sugar was sold in Vancouver. This time the customers would not be charged for any freight, and the company would have to absorb it, leading to a reduction in profits. Finally, the preceeding analysis seems to imply that there is a complete geographical split in the Canadian sugar market along the Manitoba-Ontario border. This is not a totally correct interpretation of the situation; B.C. Sugar makes sure that the price of refined sugar, F.O.B.Vancouver plus freight to any location in western Canada, is slightly less than the price of refined sugar F.O.B. Toronto/Montreal plus freight. The company does this so as to maintain it's market share. Given that there exists substantial excess capacity in the Canadian sugar refining industry, if the firm did anything else, the reduction in its sales would be both immediate and permanent. Of course, transportation charges buffer the sugar beet industry from potential competition from eastern refiners; implying that price fluctuations for beet sugar will not likely be perfectly correlated with those that occur in the international market. Therefore hedging on the international market does not provide a means for avoiding the risk associated with not knowing the price to be received at harvest when planting in the spring, i.e., the price of refined beet sugar must be treated as a stochastic variable in any theoretical consideration of the contract.

II.3. The Internal Structure of the Beet Sugar Industry

Since the turn of the century, beet sugar has accounted for between 35% and 60% of the world's sugar output.[23] As has been mentioned earlier, of the ten refineries in Canada, only three - those in Alberta and Manitoba, and in St. Hilaire, Quebec - refine sugar from domestically grown beets: approximately 10% of the sugar sold in Canada is produced in this manner. Over the last decade, approximately 50% of the beets were grown in Alberta, 40% in Manitoba, and 10% in Quebec.

In southern Alberta, for instance, approximately 700 farmers grow sugar beets which are processed by the factory located in Taber. In the early spring, the refiner signs contracts with the individual farmers. Included will be a provision specifying the number of acres to be seeded. During most years this stipulation is unimportant, since the individual farmers have an acreage allottment which is highly stable over time. However, we must point out that if conditions warrant, the refiner will alter the level of contracted acreage. For instance, in 1982 Canadian Sugar Factories Ltd. reduced each farmer's acreage by approximately 20%. Also important, and interesting, is the method by which the farmers are paid for their beets. For other cash crops, such as tomatoes, the growers are guaranteed a price for their product before they seed in the spring. The sugar beet contract, however, is quite different. The refiner extracts the sugar from the beets then sells it according to the basing-point pricing scheme. After all refining costs are subtracted from gross sales revenue, the refiner and farmers share what is left. The farmers will receive between 58% and 63% of the value of the refined sugar produced from that year's crop: the share being determined by the price (net of refining costs) received for the sugar.

If the net price does not exceed $138.00 (fall below $154.00) per tonne, then the farmers' share will be constant at 58% (63%). It is only in the intermediate range of prices that their share will be an increasing linear function of the net price. We do recognize, however, that for more than twenty years, the actual net price of refined sugar has been sufficiently high - not less than $154.00 per tonne - so that the farmers' share has been constant at 63%. Once the overall payment to the farmers is determined, the individual farmer then receives a fraction of this: the fraction being equal to the proportion of total sugar beet production that his output represents.[24] The contract also has other provisos relating to the purchase of seed, spoilage, etc., but they are all relatively unimportant. More crucial is that which is left out of the contract. In the tomato industry, for instance, the processor keeps a very close watch on the activities of the individual farmers. If they do not care for their crops correctly - spray for insects at the right time - then the processor will do the work, and charge the farmer for it: the contract allows the processor to force 'appropriate' behavior from the farmer. In a sense, the tomato farmer is not permitted any independent choices. The situation in the beet producing industry is quite different. With the exception of contracted acreage, the refiner does not force any behavior on the part of the farmers. For instance, the farmer can decide when and whether to apply fertilizer to his crop; the refiner chooses not to directly influence this decision. We speculate that this fundamental difference in the contracts signed by the beet and tomato producers can be traced to the following factor. While sugar beets are a hardy crop, tomatoes are much more sensitive to environmental shocks. It follows that the tomato processor would try to avoid them by monitoring the farmers very carefully, and force them to do the work when necessary. Therefore, the low benefit to monitoring input usage in the beet industry implies it is not worthwhile to sustain the cost of monitoring.

The payment scheme in Quebec on the other hand, is, in one important respect, quite different. In this case the farmers are guaranteed a fixed price per ton for their beets: that price being determined so as to assure that the refined beet sugar will be competitive with the sugar refined from imported raw cane. This difference in contractual arrangements is important because of their associated risk-bearing characteristics. In the former, the farmers are bearing part of the risk associated with fluctuations, for instance, in the price of refined sugar. Not surprisingly, in the latter it is the Quebec government - the refiner in this case - that is bearing all of the risk. This comparison indicates that a substantial divergence in their respective attitudes towards risk cannot be ruled out among sugar beet refiners.

In our discussion of the cane refining industry, we considered the protection accorded it by tariffs and transportation charges. Murti (1972) also considered the impacts of the same factors on the beet refining industry. She calculated the effective rate of tariff protection to be 145.73%, while the nominal rate was 15.6%. Even more important is the natural protection from the eastern Canadian refiners which is provided by internal freight costs. B.C. Sugar makes sure that the delivered price of their product falls below the delivered price of Toronto and Montreal sugar. Given the advantage in freight costs that the beet refiner has in western Canada, its profits are being protected. In fact, Murti calculated an effective rate of natural protection of 508.59%.[25] While the existence of protection does not necessarily imply high profits, B.C. Sugar's profits are clearly higher than they otherwise would have been. At this point, we must ask why there has not been any entry into this industry. Two reasons present themselves. First of all, the collusive behavior of the Canadian sugar refining industry prevents one of the eastern refiners from upsetting the applecart in western Canada. And second, the substantial excess capacity of B.C. Sugar would deter entry because of a fear of price cutting.

The nature of the contractual arrangement that exists between the beet refiners and the farmers might lead us to conclude that the farmers are also being protected. But, here, we must tread carefully. The concept of the effective rate of protection provides a measure of the protection being accorded the value added in the refining process. Hence, the results summarized above cannot be used to discuss the protection being received by the farmers. Murti recognized this problem, and measured - directly - the protection being received by the farmers. For the primary production of sugar beets, she calculated an effective tariff rate of 17.73%, and an effective rate of natural protection of 23.19%. While the overall protection received by the farmers is only a fraction of that received by the refiner, it is still significant. Using the same data, the Tariff Board (1971) calculated a dollar value for these two forms of protection. Table II-D summarizes their results. When the information underlying this table was collected, the farmers were receiving between $12.00 and $13.00 for their beets.[26] As is indicated above, one-third of this can be traced to the two forms of protection.

Table II-D

Effects of Protection on Sugar Beet Producers

	Effect of Tariff Protection ($'s per ton of beets)		Effect of Natural Protection ($'s per ton of beets)	
	Que.	Man. & Alta.	Que.	Man. & Alta.
1967	1.82	2.00	0	2.36
1968	1.98	2.13	0	2.16

Source: Tariff Board Report No. 146 (1971).

II.4. Modelling the Contract between the Sugar Beet Processor and the Producers

In attempting to model the relationship between the refiner and growers of sugar beets, we must concentrate on two factors. First, there is the payment scheme that is specified in the contract. As shown below, in recent years the farmers - as a group - have received between 58% and 63% of the 'average net price' of the sugar that is sold. After the beets are delivered to the factory, the sugar is extracted[27] and sold at a price determined by outside factors. An average selling price for that year's crop is calculated, and after all refining costs are subtracted from it, the average net price is determined.

Let us recall that the market structure is one of monopsony in the beet processing industry in western Canada. Given this situation, we should not be surprised to find that 'real' negotiations regarding the nature of the contract do not take place between the refiner and representatives of the sugar beet growers. It is for this reason that when we model the producer-processor relationship in Chapter IV, we treat the characteristics of the contract as being determined by the processor, rather than as the result of a bargaining process.

Table II-E

Farmers' Payment Under the Sugar Beet Contract

Average Net Price for Sugar ($'s per tonne)	Growers' Share of The Average Net Price
138.00 and under	58%
142.00	59.25%
146.00	60.5%
150.00	61.75%
154.00 and over	63%

Source: 1981 Sugar Beet Contract.

The second factor which is important in modelling the relationship between the refiner and growers of sugar beets is the nature of the production process. The beets are seeded in the spring; after the payment for that year's crop is determined. But the refiner has no way of directing influencing the behavior of the farmers. For instance, several times during the growing season, water and fertilizer have to be applied to the crop, and the beets have to be thinned. It would be to the refiner's advantage if he could costlessly monitor the farmer's activities: a profitable incentive contract based on input usage could then be designed. The sugar beet contract does not, however, include this type of monitoring as a proviso. The rationale for the non-inclusion is presumably very straightforward: effective monitoring is quite simply not profitable.

The discussion of the previous few paragraphs indicates that both the refiner and the farmers have variables they unilaterally control: the processor determines the characteristics of the contract, while the farmers have complete control over the primary production of beets. In Chapter IV we consider the relationship which exists between the attitudes toward risk of the refiner and farmers, and the characteristics of the contract and fertilizer use. This will be done through the development and analysis of a stochastic framework which follows the principal-agent paradigm. A deterministic model is not used because the agricultural sector is inherently risky. For instance, the farmers - at least those in western Canada - do not know what price they will receive for their beets when they plant them in the spring. In fact, they don't even know, when the beets are harvested in the fall and delivered to the refinery. It might be argued, however, that since a well developed market in the trading of sugar futures exists, hedging will provide a means for avoiding the risk outlined above.[28] Since there is no certainty as to how much refined beet sugar will be shipped to different locations when the contract is signed, the transportation charges associated with basing point pricing will prevent the futures market price in New York and the local (Alberta) price from being equal. It follows that the net price received for the refined beet sugar is subject to unavoidable risk, and that the use of a stochastic framework to model the refiner-farmer relationship is appropriate.

II.5. Concluding Remarks

In this chapter, we have examined the sugar refining and beet-producing industries in Canada. Most of the sugar consumed in Canada is refined from raw cane. It is obtained primarily from countries which are subject to the British Preferential tariff, and is purchased on the 'free market'. Once the raw cane has landed, it is refined then sold under a basing-point pricing marketing strategy. Only 10% of Canada's sugar requirements are obtained from domestic sources. Sugar beets are currently being grown in the three areas of the country: in Alberta, in Manitoba, and in Quebec. The sugar obtained from beets is sold under a basing-point pricing scheme, and the farmers are paid, through the receipt of a proportion of the net-revenue obtained from sales of beet sugar. In the chapters that follow, we will analyze the contractual arrangement that currently exists between the processors and producers of sugar beets.

Endnotes

1. Sections 1 and 2 of this chapter draw heavily upon the material contained in Tariff Board Report No: 146 (1971), Food Prices Review Board Report (1974), and Food Prices Review Board Report (1975).

2. Up until 1967, sugar beets were grown in southern Ontario.

3. The degree of polarization is a measure of the purity of the sucrose. Sugar with 100 degrees of polarization is pure sucrose, while sugar is said to be 'raw' if it tests out at less than 99.8^{o} of polarization.

4. See Tariff Board Report No. 146 (1971), p. 179.

5. The U.S. Sugar Act expired in 1974. Since then the United States has purchased raw cane on the free market. At present there appears to be some pressure building in the U.S. Congress for a reenactment.

6. See Food Prices Review Board Report (1974), p. 15.

7. One long ton = 2240 pounds.

8. Many of the countries which trade sugar under preferential agreements have also signed the series of International Sugar Agreements.

9. See Food Prices Review Board Report (1974), p. 17.

10. See Food Prices Review Board Report (1974), p. 18.

11. A more detailed breakdown of the pricing mechanism may be found in Tariff Board Report No. 146 (1971), p. 110-20.

12. The terminology is that of Grossman (1979b); see p. 352-54.

13. See Grossman (1979b), p. 354.

14. See Tariff Board Report No. 146 (1971), p. 47.

15. The price is for raw cane of 96^{o} of polarization, and the price does not include British tariffs.

16. The M.F.N. tariff rate for sugar of less than or equal to 76^{o} of polarization is \$0.45 per one-hundred pounds. For each additional degree of polarization (or portion), there is an extra \$0.015 per one-hundred pounds. Once the degree of polarization reaches 99.5^{o}, but is less than 99.7^{o}, the rate is \$1.10; beyond 99.7^{o}, it is \$1.20.

17. See Food Prices Review Board Report (1975), p. 17.

18. See Food Prices Review Board Report (1975), p. 17.

19. See Tariff Board Report No. 146 (1971), p. 170.

20. In order to calculate the effective rate of protection for the cane refining industry, input-output data is required - Murti obtained this information from the Tariff Board's report. Unfortunately, that information has not been made available for subsequent years. Hence, we cannot bring Murti's study up-to-date.

21. See Scherer (1970), p. 267.

22. See Food Prices Review Board Report (1975), p. 19.

23. See Tariff Board Report No. 146 (1971), p. 6 and 217.

24. The Manitoba contract is, in all important aspects, identical.

25. As with cane refining, obtaining recent input-output data on the beet refining industry is impossible; hence, Murti's study cannot be updated.

26. In 1967, the return to growers was $12.04 per ton; in 1968, $12.91.

27. A description of the process may be found in Tariff Board Report No. 146 (1971), p. 24.

28. See Holthausen (1979).

CHAPTER III

SURVEY OF THE LITERATURE

III.1. Introduction[1]

Under the terms of the sugar beet contract, the refiner and the growers 'share' the net revenue generated by the sale of refined beet sugar. Traditionally, economists have viewed share contracts with disdain: they felt that this method of allocating resources would lead to inefficiency. This view can be traced back to Adam Smith, who treated sharecropping as being an intermediate step between slave cultivation and fixed-rent contracting. One point which Smith made has had an especially strong influence on future investigators. He wrote:

> the lord, who laid out nothing was to get one-half of whatever it (the land) produced. The tithe, which is but a tenth of the produce, is found to be a very great hinderance to improvement. A tax, therefore, which amounted to one-half, must have been an effectual bar to it.[2]

Smith was clearly drawing an analogy between an excise tax, and sharing arrangements.

While further work was done in the intervening years,[3] it was left to Marshall (1966) to make the next major advance in analyzing sharing arrangements. He carried forward the tax analogy, and used his marginal analysis to characterize the allocation of resources under sharecropping. Following Cheung's description of Marshall's analysis, let us assume that labor is the only variable factor of production. If the landlord was to choose the quantity of labor to be hired, equilibrium will be determined where the marginal product of labor equals labor's opportunity cost; the exogenously determined wage rate (w).[4] In Figure III-A, the equilibrium will be determined at B.

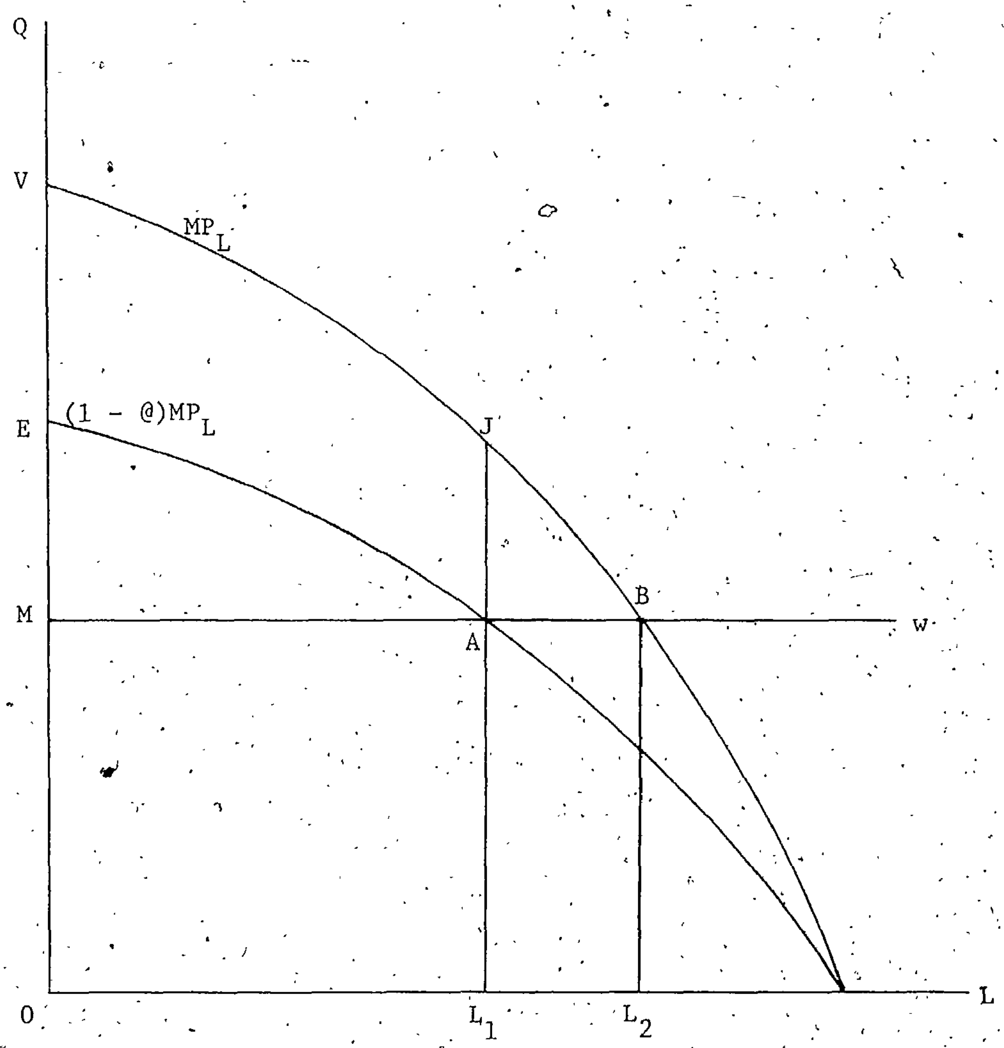

Figure III-A

We should also note that the same allocation of resources would be observed under rent contracting: where the landlord is paid a fixed amount per acre and the laborer (the tenant) determines labor input levels. Thus, rent contracting can be seen to lead to an efficient allocation of resources.

Let us now alter the arrangement and allow the landlord to be 'paid' for the use of his land through the receipt of a proportion (θ) of the harvested crop, while the the tenant receives the remaining output and chooses the amount of his labor to be applied to the production process. Under these circumstances, labor will be applied to the point where the marginal product of labor - from the perspective of the tenant - equals the tenant's opportunity cost; that is, $(1-\theta)MP_L = w$. In terms of Figure III-A, the equilibrium position will be determined at A. We observe, however, that at this position, the opportunity cost of the tenants labor is exceeded by the 'true' marginal product of that labor. For this reason, we note that sharecropping leads to an underutilization of resources, and inefficient production.[5]

Several researchers have sought empirical evidence vis-a-vis this last result. Rao (1971) finds that in India, "output per acre at the margin, that is, for a unit increase in land at its geometric mean is higher among the owner-operated farms compared with the share-rented farms, indicating that, on the average, land is cultivated more intensively by owner-operated than by share-rented farms."[6] This result is supportive of Marshall's analysis. On the other hand, Bray (1963) argues that much of the gain in productivity in U.S. agriculture observed in the last few decades is due, indirectly, to sharecropping. He suggests that share tenancy has permitted the establishment of larger farms, and this has, in turn, led to a more efficient scale of operation.[7] Buck (1930) observes that, in China, if yields were classified by owner-cultivation, rent, and share tenancy, no significant variation was observed. "Apparently, tenant farming for the places studied does not mean inefficient farming. In some places, even, it is evident that the tenants farm better than the owners."[8]

The empirical evidence summarized in the previous paragraph indicates that in some cases, sharecropping is no less efficient than rental contracting; a result which is in clear conflict with the Marshallian analysis. This leads us to question whether the Marshallian equilibrium will, in fact, exist: this issue has been raised by Cheung (1969), Reid (1977), and Sutinen (1973). Referring back to Figure III-A, we observe that under rent contracting, the area MVB represents the total rent collected by the landlord,[9] while $OMBL_2$ measures the total receipts of the tenant. On the other hand, under a sharecropping scheme, the total product - as represented by $OVJL_1$ - is divided as follows: the landlord receiving an amount EVJA, with the tenant receiving $OEAL_1$. Upon characterizing the two schemes in this manner, we find that the payment obtained by the landlord under rent contracting exceeds that received under sharecropping. Hence we find that the Marshallian equilibrium - position A in Figure III-A - is illusory; it will never be observed in a non-stochastic world.[10] Of course this conclusion will not, in general, follow if imperfect competition, monitoring costs, or distortions in the labor or capital markets exist - see Jaynes (1982) and Lucas (1979).

III.2. Summary of the Modern Non-Stochastic Literature

The more recent non-stochastic literature has followed two divergent approaches in considering tenancy agreements. The works of Bardhan and Srinivasan (1971, 1974) and Reid (1976) have viewed the contract between the landlord and tenant as being determined in a competitive environment. On the other hand, Cheung (1969) has viewed the landlord as being able to choose the characteristics of the contract - though subject to a constraint. As we shall report below, the two approaches lead to quite different implications regarding the efficiency of sharecropping.

Bardhan and Srinivasan consider two individuals: the first "a landless person (who) has the option to lease in some land and cultivate it with his labor or to work as wage-laborer on somebody else's farm or in non-agricultural occupations. In the former case he gets the output from the leased-in land after payment of a percentage share to the landlord and in the latter case, he receives a wage rate per unit of labor."[11] Given the parametrically obtained wage rate and the rental share, this individual chooses the amount of land to be leased, and the allocation of his time to leisure and the two types of effort so as to maximize his welfare. Upon noting the essentially Marshallian nature of this decision, we are not surprised to find that labor will be underutilized on the leased land.[12] They also demonstrate that the demand for leased land is positively related to the proportion of output received by the tenant.

We now examine the supply side. "The landowner has the option to cultivate land with the use of own and hired labor or to lease out land to sharecroppers. In the former case, he has to pay hired labor at the given wage rate and in the latter, he gets only a share in the tenant's output."[13] Once again, given the wage rate and the rental share, the landlord chooses the amount of land to be leased out, and the amounts of his own and hired labor to be used on the non-leased land, so as to maximize his welfare. Bardhan and Srinivasan demonstrate - in the neighborhood of the equilibrium - how the supply of leased land is inversely related to the proportion of output received by the landowner.[14]

Bringing together the demand and supply for leased land, a stable equilibrium is achieved: concurrently, the rental share will be determined out of the aggregated decisions of landlords and tenants. Bardhan and Srinivasan's approach would clearly be inappropriate in modelling the sugar beet industry because while the farmers take their share of profits as given, the refiner does not; he's a monopsonist. Even if there were large numbers of individuals on both sides of the transaction, the validity of treating the rental share in this manner is questionable. In a competitive framework, the parametric variable is a price-like variable, in that it permits us to value the item. In this case, however, the rental share does not "represent the exchange value of a unit of land in terms of some numeraire."[15] Hence, the applicability of the competitive framework is brought into question. Their approach can also be criticized because it ignores the fact that rental and share-contracting, and owner cultivation co-exist. That is, the entire question as to the illusory nature of the Marshallian equilibrium is completely ignored.[16]

Newbery (1974) criticized the treatment of Bardhan and Srinivasan and pointed out that a competitive equilibrium will not exist under their approach. To be precise, he argued that a competitive equilibrium would not exist because of an excess supply of tenants. In their response, Bardhan and Srinivasan (1974) do not provide an existence proof, and acknowledge that while the typical tenant's income under a share contract would exceed his opportunity wage, this would not prevent an equilibrium in the market for leased land.

The approach followed by Reid (1976) is similar to that of Bardhan and Srinivasan; though there are a few important differences. He considers a tenant who maximizes his income "with respect to only those variables he unilaterally controls: the time allotted to work for wages ..., the labor-land ratio on rented land ..., the amount of land he desires to rent ..., and the amount of land he desires to sharecrop ... ."[17] Given the constraint that the tenant be fully employed, the amount of his labor to be allocated to sharecropping is determined in a residual fashion. Similarly, "each landowner maximizes his income ... subject to the constraint that his land is fully employed ... with respect to those variables he unilaterally controls: the land supplied for renting ..., the land supplied for sharecropping ..., and the ratio of labor to land in owner cultivation ... ."[18] Finally, both individuals treat the wage rate, the rental rate on land, and the crop shares as parameters.

A full equilibrium in Reid's framework will include counterbalancing decisions by both individuals with respect to the amounts of rented and sharecropped land. Also determined will be the crop shares, the rental and wage rates: in this way Reid's treatment represents an extension of Bardhan and Srinivasan's analysis. That both the rental rate, and the crop share are determined endogenously is important because this corrects the problem outlined in the previous section. Reid demonstrates that the marginal products of labor and the labor/land ratios under owner cultivation, rental and share contracting are identical. These results are important because they indicate that the three types of cultivation are equally efficient; Marshall's view is incorrect. While Reid's solution represents a definite improvement over that of Bardhan and Srinivasan, once again, we cannot apply this framework to the sugar beet industry. The reason being that our monopsonistic refiner quite clearly does not take the characteristics of the payment scheme as given.

While there are certain differences in the frameworks developed by Reid, and Bardhan and Srinivasan, in both cases a competitive framework is used. Cheung's conceptualization of the problem is quite different; he views the landlord as being able to determine the characteristics of the tenancy arrangement, rather than having them being determined competitively - as above. However, the landowner is subject to a constraint: he must offer the tenant an income level under sharecropping which precisely equals that which would be earned under a wage contract; otherwise competition among potential tenants would force a reduction in the tenant's market share.[19]

The framework developed by Cheung includes one extremely important assumption: the contract outlined in the first order conditions includes a specification of tenant effort. While not formally stated, it is assumed that the landlord is able to monitor the effort of the tenant in order to guarantee that the contract be fulfilled. This is important because if the decision was left to the tenant, labor would always be underallocated - for the reason outlined in Marshall's analysis. This result leads us to question whether the input levels for all factors of production can be effectively monitored by the landlord. In general, it seems clear that while the landlord may be able to monitor the input levels for certain factors of production, others can't be. Thus Cheung should have recognized, but didn't, that the tenant can make decisions which influence the return from sharecropping, but which are outside of the share-contract.[20]

In considering the sugar beet industry, we find that Cheung's methodology is applicable to this particular case. Indeed, there is an individual who chooses the characteristics of the contract - the refiner - while there are other individuals who take the characteristics of the contract as given - the farmers. However, a modification of his approach is required since the choice over all variable factors of production is left to the individual farmer. While they are not included in his theoretical framework, Cheung specifies two reasons as to why share and rent contracting would co-exist - the cost of negotiating and enforcing contracts, and risk.[21] Without the benefit of any empirical evidence, he asserts that "contracting on a share basis appears to involve higher transaction costs as a whole (the sum of negotiation and enforcement costs) than a fixed-rent ... contract."[22] He reasons that the landowner would have to monitor the tenant under share tenancy, but not under a rental agreement. Hence the differential in transaction costs would always prevent the total dominance of a share contract. But the available evidence contradicts Cheung's assertion. Reid (1973, 1976) found in his study of post-bellum Southern landlords that "rental contracts were .... costly to negotiate and enforce."[23] In fact, "rental contracts resembled their sharecropping counterparts in paying much attention to the details of land use and of maintenance duties. Landlords often placed specific contractual restraints upon renters to guard against the deterioration of land and capital ... . To ensure that renters would pay their rents and honor their contracts, landlords often supervised their work."[24] Generally speaking, all contractual arrangements are costly to negotiate and enforce, and the safest strategy is to avoid assuming a cost advantage to one particular form.

Even if Cheung was correct in his assertion, his resulting conclusion would only be valid in the case where the landlord can perfectly monitor the tenant. It follows that if the tenant is allowed to independently choose the level of application for one, or all, variable inputs, then the negotiation and enforcement costs may be lower than presumed. Hence, we find that the absence of monitoring may lead to a lowering of in transactions costs, thereby increasing the likelihood of a share contract with no monitoring of inputs.[25]

Cheung argues that risk spreading is one of the most important attributes of share tenancy. "Under a fixed-rent contract, the tenant bears most, if not all, of the risk; under a wage contract, the landowner .... Share tenancy may then be regarded as a device for risk sharing (or risk dispersion); that is, the variance of output yield is distributed among the contracting parties. Given the postulate of risk aversion, a share contract will be mutually preferred by the landowner and tenant."[26] Unfortunately, Cheung did not develop a formal model to analyze these problems. The main thrust of this thesis is the development of an internally consistent framework which permits an analysis of these issues within the context of the sugar beet industry. We recognize, however, that the principal-agent literature has considered similar issues: we survey this literature below.

III.3. Summary of the Stochastic Literature

The fact that agricultural production is inherently risky led to the view by various investigators, that tenancy agreements are best analyzed within an uncertainty framework. According to the typical treatment, an agreement is reached which specifies the crop shares to be received by the two individuals, and the usage rates for the inputs that the landlord can effectively monitor.[27] Implicit in this agreement will be the recognition by the landlord that there may be inputs which are unilaterally determined by the tenant.

Sutinen (1973, 1975) essentially follows Cheung's methodology, while reformulating it into a stochastic framework. A risk averse landlord chooses the characteristics of a share contract so as to maximize his expected utility, subject to the constraint that the risk averse tenant receive a level of expected utility identical to "that (which) could be realized if the sharecropper employed his assets elsewhere in the economy."[28] The sharecropper pays all costs of production, and in turn receives a proportion of the actual output; what remains is received by the landlord. Also, a revenue transfer between the two individuals is introduced "which acts to adjust the sharecropper's expected utility of income to a level where he is indifferent about employing his assets in this farming activity or elsewhere in the economy."[29] [30] He demonstrates that the optimal contract will involve both individuals receiving a portion of the farm's output.[31] Also he suggests that if both individuals were risk neutral, then "the landlord exhibits complete indifference towards share and nonshare lease arrangements."[32] This statement is incorrect and Sutinen is led into making it because nowhere in either of his papers are the second order conditions for a maximum specified. Upon checking them, we find that they cannot possibly be satisfied if both individuals are risk neutral. His approach has several other limitations: he only considers the output to be shared and not the underlying markets for inputs. Thus, he is not able to determine whether inputs are utilized efficiently under sharecropping. More importantly, by following this approach he completely ignores the possibility that the level of output may, at least partially, be under the control of the tenant. In summarizing Sutinen's contribution, we recognize that he corrects one of the problems inherent in Cheung's analysis by considering a risky situation. Unfortunately, however, he does not allow any independent decision making by the tenant. It is primarily for this reason that we cannot adopt his approach in modelling the sugar beet industry.

In Section II.2. of his paper, Stiglitz (1974) develops a framework which is methodologically identical to Sutinen's, while being substantially more complicated.[33] As with Sutinen, he considers a landlord who can choose the characteristics of the contract "subject to the constraint that he be able to obtain workers."[34] That is, the contract offered to workers must grant a level of expected utility identical to that which can be obtained elsewhere. Also, he considers the possibility that landlords and workers can mix contracts. That is, "workers can work for several different landlords and landlords can hire workers on several different contracts."[35] This generalization permits Stiglitz to specify conditions under which share contracting will lead to efficient production.[36]

Newbery and Stiglitz (1979) concentrate on the issue of whether the existence of uncertainty provides the rationale for the adoption of share contracts. They find, however, that sharecropping provides no advantages over a combination of wage and fixed rent contracts under a set of strong assumptions.[37] It follows that some imperfection must exist -

transaction costs, for instance - for sharecontracting to arise. Upon extending their analysis, they find that if the labor market is imperfect, sharecontracting will lead to a preferred situation.

The study of incentive effects refers to the examination of any type of situation in which one agent attempts to modify another agent's behavior because he has knowledge of that agent's decision making process. The term incentive effect, itself, corresponds to a measure of the impact of a change in the 'smart' agent's decision variable on the magnitude of the variable that is determined by the agent whose behavior is being modified. Both Hiebert (1978) and Weitzman (1980) raise the issue of incentive effects in a manner which makes their contributions particularly important to us. Weitzman examines various contractual arrangements which have been used in the American defense industry. Under a 'cost plus' contract, the government pays the contractor "all legally allowable costs incurred by the contractor in fulfilling the project"[38] plus a fixed payment - the profit. With a 'fixed price' contract, "the contractor agrees to fulfill the project for a fixed dollar price, which, once negotiated, will not be readjusted to include actual cost experience."[39] Weitzman recognizes that both of these contract types have problems associated with them. In the first, there is no incentive for the contractor to reduce costs, while in the second the contractor is bearing all of the risk and must be reimbursed accordingly. Through the use of an appropriate 'mix' of the two contract types characterized above, Weitzman demonstrates how the incentive associated with cost reduction can be balanced with the risk requiring a greater fixed fee, in determining the optimal contract. In this way, the contractor will be induced to reduce costs in an optimal way.

Hiebert (1978) raises similar issues within the context of a tenancy relationship. As with Sutinen (1975), the tenant pays all production costs, and in turn receives a proportion of the output; what is left over is received by the landlord. Once again, a revenue transfer is introduced "which acts to adjust the sharecropper's expected (utility of) income to a level where he is indifferent about employing his assets in this farming activity or elsewhere in the economy."[40] The major difference between the analysis of Sutinen, and that of Hiebert, relates to the manner in which input levels are chosen. According to Sutinen, the decision is made by the landlord, while Hiebert assumes that it is made by the risk averse tenant. The risk neutral landlord then chooses the crop shares and the revenue transfer so as to maximize his expected income, subject to the constraint that the tenant receive "an expected utility of net income equal to the expected utility which he can obtain elsewhere."[41] In choosing the characteristics of the contract, the landlord will take advantage of his knowledge about the tenant. That is, the landowner will be cognizant of any impacts of input usage that a change in the tenancy agreement will have.

Hiebert's view has several limitations. For instance, he does not allow the two individuals to be risk averse. More importantly, a major difficulty with Hiebert's approach relates to the way in which the incentive effects are characterized. According to his view, any change in the crop share will induce an alteration in input use. But since the tenant's welfare must be kept at the constrained level, an automatic adjustment in the revenue transfer will take place. In Hiebert's analysis, the two components of the payment scheme are adjusted with the tenant reacting to the overall change in the terms of the contract.

Unfortunately, this treatment does not recognize that the tenant will react differently to variations in the crop share and the revenue transfer; he only considers the overall modification. Finally, since the landlord and tenant make independent decisions, their individual views regarding the riskiness of production are important. Hiebert assumes that they both have the same perception regarding future events. In general, this need not hold true. In Section II.3. of his paper, Stiglitz (1974) also raises the issue of incentive effects. While his treatment is more complicated than that of Hiebert, his basic approach is identical. Thus, the criticisms made regarding Hiebert are also valid here. In summarizing the efforts of Hiebert, Stiglitz, and Weitzman, we recognize that they have corrected almost all of the problems that Sutinen left unresolved. Also, when we attempt to model the sugar beet industry their method of analysis will be directly applicable. Indeed it makes sense for our refiner to set the terms of the contract so that:

(1) farmers will be persuaded to grow beets, and

(2) the farmer's behavior (use of inputs) will leave the refiner's welfare being maximized.

Looking ahead, in Chapter IV we adopt the method of Hiebert, Stiglitz, and Weitzman, after accounting for differing attitudes towards risk, and differing views regarding the riskiness of sugar beet farming.

According to Ross (1973), "an agency relationship has arisen between two (or more) parties when one, designated as the agent, acts for, on behalf of, or as representative for the other, designated the principal, in a particular domain of decision problems."[42] Generally speaking, "the object of the principal is to provide an incentive for the agent to choose an input, from the set of feasible inputs, so as to maximize the agent's expected utility while simultaneously providing the highest possible expected utility for the principal. His only problem is to decide on the payoff function (contract) which is consistent with his own utility maximization while giving the agent enough incentive for maximizing his own expected utility and to take the risk the principal would have him take."[43] There are potential difficulties, however, the agent might choose a non-optimal level of input usage - from the perspective of the principal - if the two individuals differ in their attitudes towards risk, or if the two individuals differ in the information they have access to, and since "the agent would prefer to work less, other things equal, while the principal is indifferent to the level of the agent's effort, other things (i.e., his share of the payoff) equal."[44] Recently, several investigators have examined the characteristics of the Pareto optimal contract when incentive effects exist. This analysis represents a generalization of Hiebert, Stiglitz, and Weitzman, in that the payoff function is not necessarily linear - as it is in their analyses. The relevance of this research to our analysis of the sugar beet industry is immediately clear because the problem facing our refiner is perfectly analogous to the principal's problem as outlined above. Below we survey this literature.

For Ross (1973, 1974), "incentive problems arise purely as a consequence of diverse attitudes towards risk"[45] among the two individuals. He begins by characterizing the Pareto-efficient payoff function, then demonstrates that the payoff to both individuals will be linear function of output, and Pareto optimal, when the two utility functions are of the linear risk tolerance class.[46] Upon relaxing this restriction, he relates the concavity or convexity of the payoff schedule to the degree of absolute risk aversion for the two individuals, and more importantly, shows "what class of pay-off structures .... yields a Pareto efficient solution for any pair of utility functions."[47] In the appendix the analysis of Ross is extended through a consideration of the characteristics of the Pareto optimal payment scheme when the two individuals have differing subjective probability density functions for the random variable.

Leland (1978) generalizes Ross, in that incentive problems arise due both to a divergence in attitudes towards risk by the two individuals, and to informational differences. He begins by characterizing the optimal payment scheme when agent actions are exogenously determined. He finds that the schedule will be a concave, linear, or convex function of output as the principal's degree of risk tolerance is increasing "at a lesser rate, at the same rate, or at a greater rate"[48] than that of the agent. Thereafter, he introduces an informational asymmetry between the two individuals and observes how the optimal payment will be influenced.[49] Generally speaking, "the more pronounced are informational asymmetries, the more convex the optimal payment schedule should be."[50] This result is not surprising since it implies that the 'income' of the individual with greater information - the agent - will fluctuate less than previously. Leland then generalizes his analysis, and considers the case where the agent's action is determined endogenously, while the principal still chooses the payment schedule. Once this change is made, Leland again characterizes the optimal payment scheme. Generally speaking, the payoff to the agent will be dependent upon his actions and the state of nature. Where the principal has information regarding both the state of nature and actual output, but not the agent's action, the action can be inferred ex post. It follows that, under these conditions, the payoff function does not need to include this information and - as Leland demonstrates -- Pareto optimality can be achieved through a schedule dependent solely upon the state of nature.

Spence and Zeckhauser (1971) concentrate on incentive effects arising from differential information. The focus of their paper is to relate the extent of the principal's information to the possible optimality of the payoff function that he chooses. They find that if the agent chooses his action prior to the state of nature being known and the principal monitors both the agent's action and actual output, optimality is achieved. On the other hand, if the agent's action cannot be monitored by the principal, then this does not follow. Similar results are obtained when the agent chooses his action after the state of nature is known. These results indicate that a certain amount of information is required if the principal is to make the 'correct' choice regarding the payoff function. Whenever the information is insufficient, inefficiency will be the result, i.e. "given his limited information-monitoring capacity, his selection of the .... payoff function is a second-best exercise."[51]

The papers concerning the agency problem that we have examined to this stage, have one point in common: they all "assume that the agent's actions enter his utility function only through the payoff."[52] That is, they ignore "incentive problems which arise because the agent would prefer to work less ...., while the principal is indifferent to the level of the agent's effort, other things ... equal."[53] It was left to Harris and Raviv (1978, 1979), Holmstrom (1979), and Shavell (1979) to consider this problem, in conjunction with an informational asymmetry between the two individuals. Harris and Raviv begin by introducing two separate models of the agency relationship. In the first, (model 1) the state of nature is not known by the agent when he chooses his action, while in the second (model 2) it is. When the state of nature is observable - ex post - by the principal, the optimal contract will include the level of output and the state of nature, but not the agent's action as determining factors: this result hold for both models. As it was with Spence and Zeckhauser (1971), the agent's action can be inferred ex post, hence there is no need to include it. The optimal contract itself will be the following form: first a 'standard' output, contingent upon the state of nature, is determined, then the agent "receives an amount which depends on the standard output and perhaps on the state, plus the difference between the actual output and the standard. (The principal) receives an amount which depends only on the state.... ."[54] For instance, an encyclopedia salesman would transfer to his firm a variable percentage of the sale price, while keeping the rest - the percentage being dependent upon market conditions, i.e. commission income would become less important as market conditions deteriorated.

Upon completing this analysis, Harris and Raviv then consider the more interesting case in which - ex post - the state of nature is not observable by the principal. They find a contract which depends only on output can be dominated by one which depends on output and the risk averse tenant's action.[55] They demonstrate that the Pareto optimal contract, for model 1, involves the agent receiving a certain share depending on his output, if his actions meet a certain criteria, and nothing otherwise. In the case of the encyclopedia salesman, he would be paid according to his sales, so long as he made a minimum number of stops.

To this point in their analysis, Harris and Raviv assume that the principal is able to perfectly monitor the actions of the agent. They now relax this restriction and consider the advantages of imperfect monitoring for model, and when the principal cannot observe the state of nature. Their monitor of the risk averse agent's action provides "information that is independent of the state of nature and allows the principal to detect any shirking by the agent with positive probability."[56] They find that the optimal contract will include the imperfect monitor - Shavell (1979) obtains a similar result - and will be dichotomous in nature. That is, "if the results of the monitoring reveal the action to be acceptable, the agent is paid according to a predetermined schedule; otherwise the agent received a less preferred fixed payment (e.g. he is dismissed)."[57] The predetermined payment should be a function of output and the monitor of the agent's action. Harris and Raviv find that there will be gains from monitoring unless either the principal is able to observe the state of nature or the agent is risk neutral.

Holmstrom (1979) criticizes the monitor used by Harris and Raviv. He argues that "such monitors are of limited interest ... since they are equivalent to observing the agent's action directly."[58] Generalizing their analysis, he introduces a monitor which provides information about the agent's action beyond that already included in the magnitude of output, and finds that it will be used to alter the characteristics of the optimal contract. It should be mentioned, however, that this result is obtained in a framework analogous to model 1 of Harris and Raviv. Recognizing this limitation, Holmstrom examines the case of asymmetric information - model 2 - and finds that the result noted above is still, under almost all circumstances, still applicable.

Hurwicz and Shapiro (1978) adopt the methodology outlined above while assuming the principal knows that the agent's utility function belongs to a particular class, but does not know "about which element of this class he faces."[59] They find that when the agent's disutility toward effort is quadratic and the payment scheme is linear, an equal division of the spoils is optimal. The problem facing us in Chapters IV and V is similar in that we will try to relate the individual terms of the sugar beet contract, to the attitudes toward risk of the refiner and farmers. There are several important differences, however. First of all, our payment scheme is more general since we allow for a lump-sum transfer while Hurwicz and Shapiro do not. Second, we do not assume specific functional forms for the utility functions, etc., whereas they do. And finally, we account for the various incentive effects explicitly, whereas they are implicit to Hurwicz and Shapiro's analysis.

In the last few pages we have summarized the recent literature on agency relationships. The importance of this research to ours is clear because a general principal-agent relationship is analyzed. In fact, the frameworks developed in these papers are, in some aspects, less restrictive than the one which we shall develop in Chapter IV. For instance, we treat the payment scheme as being linear, while the 'optimal' schedule may well be non-linear. The rationale for considering the more restrictive case is that, otherwise, a complete characterization of the payment scheme is impracticable, i.e., it would then be impossible to relate the risk bearing characteristics of the contract to the attitudes towards risk of our refiner and farmers - an issue we raise in Chapter IV. Another difference between our treatment and those outlined above is the timing of the final determination of the characteristics of the payment scheme. In our case, the principal chooses the proportions of ouput to be received by the two parties prior to any knowledge of the actual outcome, i.e., the terms of the contract are independent of the actual state of nature. On the other hand, in Harris and Raviv (1978,1979) the terms of the payment scheme at the point of 'sharing' are, in fact, dependent upon the state of nature. Their analysis, quite clearly, represents a more general case, however, it does not permit a characterization of the payment scheme in terms of the characteristics of the principal and agent. For this reason, we consider the more restrictive case. The most important difference between our treatment and their's is one of emphasis. We focus on a given decision framework and consider its implications, whereas they try to determine the characteristics of the 'best' framework for allocating resources. To be more precise, we show how the principal (refiner) will choose the contract in response to his understanding of the agent's (farmer's) behavior pattern. On the other hand, Harris and Raviv, for instance, concentrate on informational asymmetries that may exist between the two parties, and how the optimal contract will be determined by the information available to the principal.[60] And finally, whereas these papers treat the principal and agent as having identical perceptions of future events, we consider the case in which their perceptions may differ.[61]

III.4. Concluding Remarks

In this chapter, we have surveyed the literature which is relevant to the theoretical framework which is developed in the body of this thesis. While there were precursors, Marshall's analysis represented the first modern treatment of tenancy agreements. He argued that sharecropping was inefficient because the tenant only received a portion of the value of this labor. But it was recognized - according to his model - that the landlord would receive less 'rent' than under either wage or rental contracting, and share tenancy could never be observed. The reason for the internal inconsistency was traced to the fact that under sharecropping, the tenants were being paid more than the opportunity cost for their labor.

The next important work was that of Cheung (1969). He formulated a system in which the landlord is able to choose the characteristics of the tenancy contract, so long as the tenant is paid his labor's opportunity cost. We recognized that while he had implicitly assumed that the landlord was able to costlessly monitor the usage rates for all inputs, this needn't be the case and not monitoring may in fact be the optimal outcome.

Generally speaking, the stochastic literature recognized the inherent riskiness of agricultural production, and has modified Cheung's framework to account for it. In future chapters, we will adopt the principal-agent paradigm in our attempt to model the relationship that exists between the refiner and growers of sugar beets.

Endnotes

1. This section draws heavily on Cheung (1969).

2. See Smith (1937), p. 367.

3. See Jones (1964) and Mill (1929).

4. The wage is measured in units of output.

5. A similar result is obtained in Cheung (1968, 1969), Heady (1947), Johnson (1950), and Markusen (1975). The situation where the landowner bears a portion of the input costs is analyzed in Adams and Rask (1968, 1969), Boxley (1971, 1972), Gisser (1969), and Kim (1972).

6. See Rao (1971), p. 589.

7. Bray's argument would not be affected if it was through rental contracting that a more efficient scale of operation was achieved. However, he recognizes that "the most impressive gain in agricultural productivity occurred ... where the dominant form of land tenure is a share rental arrangement between landlord and tenant" — Bray (1963), p. 25.

8. See Buck (1930), p. 157. Bell (1977) tested the Marshallian position using data from India and found broad support.

9. This would also represent the profit obtained by the landlord under owner cultivation.

10. Bell and Braverman (1981) also point this out.

11. See Bardhan and Srinivasan (1971), p. 48.

12. See Bardhan and Srinivasan (1971), p. 49.

13. See Bardhan and Srinivasan (1971), p. 50.

14. This unusual result follows because an increase in the landlord's rental share would lead the tenant to reduce his effort in farming the leased land. In general, however, the landlord will react to a reduction in the tenant's effort by cutting back on the amount of land he leases to sharecroppers. Bringing together these two arguments, we find an inverse relationship between the landlord's rental share and the amount of land allocated to sharecropping.

15. See Bardhan and Srinivasan (1974), p. 1068.

16. Lucas (1979) considers a situation somewhat similar to that of Bardhan and Srinivasan (1971). That is a tenant determines the amount of effort to apply to the land being sharerented and for wages. While the landlord determines the amount of effort to hire at a

given wage, and the terms of the contract. The situation differs from Bardhan and Srinivasan, however, in that the landlord both must supervise the labor he hires, and make "decisions subject to the reaction curve of tenants" - Lucas (1979), p. 509. It follows that sharecontracting no longer automatically leads to an inefficient allocation of resources. The reason being that both share and wage contracts involve a tax: the share in the case of sharecropping, and the opportunity cost of monitoring in the case of fixed wages.

17. See Reid (1976), p. 555.

18. See Reid (1976), p. 556.

19. A third potential solution of the sharecropping problem makes use of Nash's solution to the two-player cooperative bargaining game. See Bell and Zusman (1976).

20. This was recognized by Bardhan and Srinivasan (1971), and Reid (1976).

21. See Chapter IV of Cheung (1969).

22. See Cheung (1969), p. 67.

23. See Reid (1973), p. 569.

24. See Reid (1973), p. 569 and 570.

25. Reid (1973) suggests that sharecropping has additional incentives. He argues that share contracts can be altered relatively easily in order to take advantage of fluctuations in weather, etc., while this does not hold for rental contracts.

26. See Cheung (1969), p. 68.

27. Jaynes (1982) examined how capital market imperfections would lead to sharecontracting.

28. See Sutinen (1975), p. 615.

29. See Sutinen (1975), p. 615.

30. An advantage of Sutinen's framework is that is allows for the joint consideration of rental and share contracting. Unfortunately, he does not recognize this.

31. See Sutinen (1973), p. 48-51, and Sutinen (1975), p. 615 and 616.

32. See Sutinen (1975), p. 616.

33. In Part I of his paper, Stiglitz concentrates on the efficiency and risk sharing aspects of sharecropping.

34. See Stiglitz (1974), p. 227.

35. See Stiglitz (1974), p. 219.

36. See sections I.1.3., I.1.4., and II.2. of Stiglitz (1974).

37. See Quibria and Rashid (1984), p. 109.

38. See Weitzman (1980), p. 721.

39. See Weitzman (1980), p. 721.

40. See Sutinen (1975), p. 615. Hiebert recognizes how the introduction of the revenue transfer allows for the joint consideration of rental and share tenancy.

41. See Hiebert (1978), p. 536.

42. See Ross (1973), p. 134.

43. See Mirman (1974), p. 238.

44. See Harris and Raviv (1978), p. 20.

45. See Harris and Raviv (1978), p. 20.

46. The degree of risk tolerance is the inverse of the degree of absolute risk aversion.

47. See Ross (1973), p. 137.

48. See Leland (1978), p. 425.

49. The agent receives a 'signal' regarding the value of the output to be shared.

50. See Leland (1978), p. 425.

51. See Spence and Zeckhauser (1971), p. 387.

52. See Harris and Raviv (1979), p. 235.

53. See Harris and Raviv (1978), p. 20.

54. See Harris and Raviv (1978), p. 20.

55. See Proposition 4 in Harris and Raviv (1979). For this to be valid in model 2, the agent's utility function must be separable, and the production function must be one to one vis-a-vis the state.

56. See Holmstrom (1979), p. 75.

57. See Harris and Raviv (1979), p. 247.

58. See Holmstrom (1979), p. 75.

59. See Hurwicz and Shapiro (1978), p. 181.

60. The presence of an information asymmetry has also raised questions concerning the existence of an equilibrium in the competitive insurance market. According to the standard treatment, two groups of individuals differ in only one respect: their respective probabilities of having an 'accident'. The asymmetry exists in that the individuals know to which risk category they belong, while the insurance companies do not. Given this situation, the insurance market can have equilibria of only two types: "pooling equilibria in which both groups buy the same contract, and separating equilibria in which different types purchase different contracts" - see Rothschild and Stiglitz (1976), p. 634. Ahsan, Ali, and Kurian (1982), Rothschild and Stiglitz (1976), Stiglitz (1977b), and Wilson (1976) examined situations under which pooling and separating equilibria were likely to exist.

61. Much of the stochastic literature that we have surveyed has been concerned, either implicitly or explicitly, with the optimal allocation or risk between individuals. That is, 'gains from trade' can arise typically out of either informational asymmetries, or a difference in attitude towards risk among individuals. But all of this analysis has been done at the firm level. Recently, quite a bit of research has been done on contract structure and risk sharing at the intrafirm level. Markusen (1979) attempts to relate the characteristics of workers to the contract that exists between them and their employer: he begins by specifying three limiting cases. A salary contract guarantees the typical worker a fixed income, while a wage contract guarantees the worker "a fixed wage per hour of work but under which there is no employment guarantee" - see Markusen (1979), p. 255. A profit sharing contract, in which the workers are paid a share of the firm's profits, represents the final 'pure contract type.' In comparing the three cases, it follows that "a profit-sharing contract involves more income variation than a wage contract, which, in turn, involves more income variation than a salary contract - see Markusen (1979), p. 258. Markusen characterizes the optimal contract, and compares it to the three limiting cases. While Markusen focused on the problem of relating employee characteristics to contract structure, the general question of an overall labor market equilibrium was left open. As is well known, labor markets chronically fail to clear. The incomplete-information hypothesis has been introduced to explain why. According to it, individuals cannot distinguish between changes in the pattern, and in the overall level of aggregate demand. For this reason, potential gains from trade are not taken advantage of - the required information is not available. However, the hypothesis has certain problems associated with it; for instance, it does not permit the existence of layoffs. Recognizing this difficulty, Azariadis (1975, 1976, 1978), Bailey (1974), Gordon (1974), Grossman (1977, 1978, 1979a, 1979b, 1981), and Polemarchakis (1979) use the idea of risk-shifting arrangements, in conjunction with the incomplete-information hypothesis, to explain why labor markets fail to clear.

They argue that a contract, implicit though it may be, between a firm and it's workers has two components: "first, firms purchase from workers labor services for use in the production process and, second, firms sell to workers insurance against undesirable income fluctuations" - see Grossman (1978), p. 663. That is, a worker's income depends upon both his marginal product and either an implicit insurance premium or indemnity, depending upon whether his marginal product is high or low: this result has been deemed the risk-shifting hypothesis. An implication of the risk-shifting hypothesis is that "although a laid-off worker would want to work if offered either the wage rate he received when he was employed or the wage rate inclusive of insurance indemnity / ... , he would typically not want to work at the wage rate that would currently clear a spot market for labor services ... " - see Grossman (1979a), p. 67. Thus accepting a layoff by a worker might be the optimal strategy, and, hence, through the joint application of the two hypotheses, we can give an internally consistent explanation of observed labor market behavior.

CHAPTER IV

AN ANALYSIS OF THE CONTRACTUAL ARRANGEMENT BETWEEN THE PROCESSOR AND PRODUCERS OF SUGAR BEETS

IV.1. Introduction

Sugar refined from beets satisfies a large proportion of the demand for sugar in the three prairie provinces. Once this sugar is sold - under a basing-point pricing scheme - the farmers are paid for their beets through the receipt of a proportion of the refined sugar's 'average net price'. Any attempt at modelling the relationship that exists between the refiner and the growers of beets will inevitably be complex because at the same time we will be concerned with the distribution of the value of production between the two parties, and the associated risk. In carrying through with this exercise, we examine what is left out of the actual sugar beet contract in order to restrict the class of contracts considered to a subset of those which are theoretically possible. For instance, nowhere in the actual contract is there a proviso relating to the 'duties' of the farmer. Acknowledging this, we assume that the costs of monitoring exceed the benefits, instead of trying to explain what characteristics in the sugar beet industry lead to a contract which doesn't involve monitoring of inputs.

In this chapter, we will examine the characteristics of the sugar beet contract. Section 2 will be concerned with the development of a stochastic model which will permit us to attack the aforementioned problem. After this has been done, the contract will be characterized in Section 3. Section 5 is devoted to comparative static analysis, in that we are interested in how the contractual arrangement is influenced by changes in exogenous factors. In the final section, some concluding remarks are made.

IV.2. A Framework for Analyzing the Sugar Beet Contract

While a large number of farmers grow sugar beets in western Canada, there is only one processor - B.C. Sugar. Given this situation, our strategy is to have the refiner determining both the characteristics of the payment scheme and the contracted acreage of the individual farmer - though subject to a constraint. Since there are other crops which offer their growers high returns, the sugar beet contract must offer terms which are competitive in order to induce farmers to grow beets.

While the refiner determines the contract, it is the farmers who have complete control over the production process. They decide when to seed, and when to apply fertilizer and irrigation water to their crop. Thus in considering their respective choice variables, the processor determines the characteristics of the contract, while the farmers control the production process.

In formalizing this relationship, we could let the refiner choose the contract on the assumption that the farmers will not change the amount of fertilizer to be applied per acre. Conversely, the farmers would choose the amount of fertilizer to be applied on the assumption that the refiner will not change the characteristics of the contractual arrangement. Through the interaction of these two decisions, the contract and fertilizer use would be simultaneously determined.

Unfortunately, this approach - when applied to the case at hand - has two major problems associated with it. First of all, the farmers must receive an adequate return, and the refiner must account for this when choosing the characteristics of the contract. But in this specification, the refiner does not realize that the farmers will react to any change in the contract structure by altering fertilizer use. If the processor recognizes the adaptive nature of the farmers' decision process, then he will take advantage of this knowledge by choosing a payment scheme and contracted acreage which will motivate the farmers to apply the optimal amount of fertilizer - from the perspective of the refiner. Berhold (1971) has named this type of analysis the study of incentive effects. Since our refiner will set the terms of the contract so as to 'guarantee' a reasonable return for the farmers, it only makes sense that he would gain some insight into their decision making process and would then try to take advantage of that insight. It follows that the above framework is clearly myopic, and it should not be used in modelling the sugar beet industry. A second major problem associated with this solution relates to the manner in which an equilibrium is attained. According to it's modus operandi, there must be sequential observations of contract terms and fertilizer use, i.e., a kind of tâtonnement process leads to an equilibrium. Unfortunately, this type of adjustment process does not appear to be at all reasonable given the case at hand.

To indicate what type of framework is, in fact, required let us backtrack for just a moment. We have a group of farmers who control the actual production of the beets; the terms of the contract being set by a refiner who is knowledgeable regarding the farmers' behavior. In modelling this type of situation, we would want the refiner to set the terms of the contract so as to motivate the farmers to apply the 'correct' amount of fertilizer; where 'correct' refers to that level which will maximize the refiner's welfare. Upon reflection, we conclude that a principal-agent framework is appropriate in modelling the relationship that exists between the processor and producers of sugar beets. In order to focus on the determination of the payment scheme, we assume a fixed number of identical farmers, i.e., they have identical preferences and contracts. This specification permits us to analyze the contract by concentrating on a 'typical' farmer.

We assume that an individual farmer's output is given by

$$Q = Ag(F),$$

where A = the number of acres on which sugar beets are grown,

F = the amount of fertilizer being applied per acre, and

g(F) = the output of refined sugar per acre as an increasing concave function of per acre fertilizer use.[1]

Once the beets are harvested in the fall and shipped to the factory the refined sugar is sold under a basing-point pricing scheme: the landed price of raw cane having determined the price at the basing point. It might be argued that because a well developed market exists in the trading of sugar futures, price uncertainty doesn't affect the production decision in the early spring. For instance if the spot price in December is greater than the futures price quoted the previous March the farmer loses on his (short) futures' market hedge but gains on the sale of the sugar refined from beets, relative to the futures' price; while if the spot price is low the farmer 'loses' on the sale of refined beet sugar relative to the futures' market price but makes up the difference by 'winning' on his 'short' hedging activity. Hedging will eliminate any risk regarding the return on sales of refined sugar, however, only if the futures price and the actual spot price (net of delivery charges) are exactly equal. Any divergence from this rule is called basis risk.[2] Since the New York futures price and the spot price in Alberta will differ due to local market conditions and transportation charges, basis risk can be expected to persist. A second, and perhaps even more important, reason as to why hedging activity will not eliminate all risk follows from our recognition that the price (net of delivery charges) will be influenced by the location of the customer. The reason being that while the sugar is shipped from Taber in Alberta, Vancouver is the basing point. Since both the refiner and the farmers will not have perfect local market (demand) information when the contract is signed, the price (net of transportation charges) received for the refined sugar is - ex ante - subject to unavoidable risk. Thus when the refiner has to decide on the characteristics of the contract and the farmers on the level of fertilizer use, the price received for the refined sugar must be treated as a stochastic variable; with basis risk (including the risk associated with market location) representing the uncertainty that is relevant to any input (production) decisions. Given that our primary concern lies in relating contractual terms and fertilizer use to attitudes toward risk, and since futures trading will not eliminate the risk associated with input decisions, we simplify matters by assuming that neither the refiner nor the farmers engage in hedging. Thus the total revenue from the sale of refined sugar is given by

$$NPAg(F),$$

where P = the ex post price per tonne of refined beet sugar net of delivery charges, and

N = the number of farmers.

Rather than sharing the revenue generated by the sale of refined sugar, the refiner and the farmers instead share what remains - net-revenue - after the refining costs are paid. Net-revenue is given by

$$NPAg(F) - C(NAg(F)),$$

where $C(NAg(F))$ = refining costs as an increasing function of the total output of sugar.

We assume a linear payment scheme; thus

$$Y_R = \theta(NPAg(F) - C(NAg(F))) + B$$

= the profit accruing to the refiner, and

$$(1 - \theta)(NPAg(F) - C(NAg(F)))/N - B/N$$

= the net-revenue accruing to the individual farmer.

An immediate criticism of our approach is that we only deal with a linear payment scheme, rather than with the more general non-linear scheme. We consider this case because it allows us to focus on the relationship between the net price of the sugar that is sold, and the proportion received by the farmers. The proportion of net-revenue accruing to the farmers - equivalently, the proportion of the net price of the refined beet sugar that the farmers are to receive - is given by the following expression

$$(1 - \theta) - \frac{B}{((P - C(NAg(F)))/NAg(F))*NAg(F)};$$

where $(P - C(NAg(F)))/NAg(F)$ equals the net price per tonne. If B is positive, it follows that an increase in the net price of sugar will lead to an increase in the farmers' share even though θ and B do not vary with the net price. By restricting ourselves to a linear payment scheme, we will be able to find conditions under which B can be signed. This, in turn, allows us to specify the conditions under which our theories predictions coincide with the actual contract. This exercise would not typically be possible if we dealt with the non-linear case, and it is primarily for this reason that we do not make the generalization.

The magnitude of B is also important for a second, and equally important, reason. If B differs from zero, the returns have two components; one deterministic and the other stochastic. The choice of payment scheme - θ and B - will unavoidably be complex because at the same time we will be concerned with two issues: the distribution of the value of production between the two parties, and the associated risk. As a specific example, let us assume - for the moment - that θ equals unity. Then B will be negative, while the farmer's revenue will be non-stochastic. However it is still possible to view the farmer's payment as being based on the net price: since $\theta = 1$, as the net price increases by 10% the proportion of it to be received by the farmers will decrease by an identical 10%, leaving their incomes unchanged. The recognition of this last point is important because it indicates that even though our farmer's payment is based on the net price, we cannot immediately make statements about his risk position; information regarding the magnitude of θ is crucial is discussing this point.

To this juncture we have been concerned with the distribution of (stochastic) net-revenue obtained from the sale of refined beet sugar. It is clear, however, that costs will be incurred in the production of the beets, themselves. We assume that any costs that the farmers contract in the production process - those associated with the use of fertilizer and the opportunity cost of land - must be paid by the farmers.

Thus $Y_T = \tilde{T} + (1 - \theta)(NPAg(F) - C(NAg(F)))/N - B/N - rAF - aA,$

= the income accruing to the individual farmer,

where r = the cost per pound of fertilizer,

a = the cost per acre of using land in beet production, and

$\tilde{T}$ = the normal return accruing to the farmer as manager and as a laborer on his own farm.[3]

Before we move on and formally specify the decision framework, we recognize that since the payments to the refiner and farmers are stochastic, it is necessary to establish their respective attitudes towards risk. We assume that for both the refiner and the farmers, if risk averse, their attitude towards risk is summarized by a Von Neumann-Morgenstern utility function. A second issue is related to the price uncertainty. The farmer will choose the level of fertilizer use given his subjective perception of the riskiness. Similarly the refiner - when choosing θ, B, and A - will base his decision on his own perception of the risk. There is no need for their subjective probability distributions to be identical; typically they wouldn't be. We account for this possibility in our formal analysis.

The farmer will apply that amount of fertilizer so as to maximize his expected utility of income. That is

$$\max_{(F)} E(U_T(Y_T))$$

where $U_T(.)$ = the farmer's Von Neumann-Morgenstern utility function, and the expectation is with respect to the farmer's subjective probability distribution on P.

We assume that the refiner will choose that contract which maximizes his expected utility of profit. However, he is subject to a constraint. The farmer could grow other crops if he were not adequately reimbursed by the refiner. Accounting for this, we assume that the contract - though chosen by the landlord - must guarantee the farmer a minimum acceptable level of expected utility. In terms of a mathematical formulation, the refiner's problem is to

$$\max_{(\theta, B, A, K)} V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

where $\bar{U}_T$ = the minimum acceptable level of utility required by the farmer,

$U_R(.)$ = the refiner's Von Neumann-Morgenstern utility function,

K = the Lagrange multiplier, and the expectations in $E(U_T(Y_T))$ follows from the farmer's subjective probability distribution on P, while those for $E(U_R(Y_R))$ follow from the refiner's.

We should point out that the decision of the refiner and that of the farmers are in a sense sequential. The amount of fertilizer being applied by the farmer will be some function of θ, B, and A.[4] The refiner is fully cognizant of this relationship and - when choosing the contract - will make use of this knowledge.

The final issue that we must raise before actually beginning the formal analysis is the nature of the individual's attitudes toward risk. We assume the farmers to be risk averse; the justification being that because of their small size, they will find it difficult to diversify risks. On the other hand, the likelihood of the refiner being able to diversify will be greater, and for this reason he will be 'less' risk averse. But taking this argument one step forward, by immediately assuming that the refiner is fully risk neutral is - we believe - too strong. On theoretical grounds we should consider both cases because while a 'large' refiner might be risk neutral, a 'small' firm may well be risk averse. Empirical evidence also supports this approach. In Quebec, the farmers are guaranteed a fixed price per ton for their beets: the refiner is bearing all of the risk. The contractual arrangement in Alberta and Manitoba is quite different. Their contracts involve the receipt of a proportion of the value of net sales of refined sugar. Because of this, their refiner is bearing only part of the risk. Thus the evidence from actual sugar beet contracts seems to support the possibility of differing attitudes toward risk by beet refiners. In our theoretical analysis we will consider both cases.

Prior to actually beginning the formal analysis, let us briefly review our conceptualization of the relationship that exists between the refiner and growers of sugar beets. In the early spring, the refiner and the individual growers sign a contract; included will be a specification of the acreage allotment (A), and the characteristics of the payment scheme (θ and B). When setting the terms of this contract, the price received for the refined sugar must be treated as a random variable. Also, the refiner is fully aware of how the growers will react to the contract when they decide on fertilizer use; where the farmers are also operating under risky conditions. It follows that specific contractual terms and fertilizer use are determined prior to the resolution of any of the inherent risk. Once the beets are harvested in the fall and the sugar is sold, the farmers will receive the following proportion of the actual net price

$$(1 - \theta) - \frac{B}{(P - C(NAg(F))/NAg(F))*NAg(F)},$$

where P now equals <u>the actual price</u> at which the sugar is sold. The sign of B is of particular importance. For instance, if $B > 0$ then an increase in the actual price will simultaneously lead to increases in the net price and in the proportion of the net price that the farmers receive. In Section 3 of this chapter, we will attempt to sign B. In Chapter V, we report the results of a computer simulation of the system; this allows us to determine how sensitive the proportion of the net price received by farmers is to changes in exogenous variables.

IV.3. Characterizing the Sugar Beet Contract

IV.3.1. Identical Subjective Probability Distributions

As was mentioned earlier, there is no need for the subjective probability distributions of the refiner and the farmers to be identical. However in analyzing the sugar beet contract, matters will be simplified if we begin with a consideration of the more restrictive case of identical distributions.

STEP I: The Farmer's Problem

$$\max_{(F)} E(U_T(Y_T))$$

The first order condition for an interior maximum is given by

$$E(U_T'(Y_T)((1 - \theta)(PAg' - C'Ag') - rA)) = 0, \tag{1}$$

where the second order condition requires that for a maximum

$$S = E(U_T'(Y_T)((1 - \theta)(PAg'' - C'Ag'' - C''N(Ag')^2)))$$
$$+ E(U_T''(Y_T)((1 - \theta)(PAg' - C'Ag') - rA)^2) < 0.$$

We recognize that (1) re-establishes the traditional inefficiency (of sharecropping) result to the case of risk averse behavior, in that the growers will underutilize fertilizer since they only receive a fraction of the value of its expected marginal revenue product.[5] Also, implicit in (1) will be a functional relationship between the amount of fertilizer being applied, the terms of the contract, and the various exogenous variables; that is, $F = F(\theta,B,A;a,r)$ — the characteristics of the farmer's probability distribution over prices of refined sugar would influence the terms of this relationship. We formalize our assumption that the refiner understands the nature of the farmer's decision process by making him fully aware of the above relationship.

STEP II: The Refiner's Problem

$$\max_{(\theta,B,A,K)} V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

The first order conditions are given by

$$V_\theta = E(U_R'((NPAg - C(NAg)) + \theta(NPAg' - C'NAg')F_\theta))$$
$$- KE(U_T'(NPAg - C(NAg)))/N = 0, \tag{2}$$

$$V_B = E(U_R'(1 + \theta(NPAg' - C'NAg')\,F_B)) - KE(U_T')/N = 0, \tag{3}$$

$$V_A = E(U_R'(\theta(NPg - C'Ng) + \theta(NPAg' - C'NAg')\,F_A)) + KE(U_T'((1 - \theta)(Pg - C'g) - rF - a)) = 0, \text{ and} \tag{4}$$

$$V_K = E(U_T(Y_T)) - \bar{U}_T = 0; \tag{5}$$

where[6]

$$F_B = \frac{E(U_T''((1 - \theta)(PAg' - C'Ag') - rA))/N}{S}, \tag{6}$$

$$F_\theta = \frac{\left[\begin{array}{l} E(U_T'(PAg' - C'Ag') + \\ U_T''((1 - \theta)(PAg' - C'Ag') - rA)(NPAg - C(NAg))/N) \end{array}\right]}{S}, \text{ and} \tag{7}$$

$$F_A = \frac{\left[\begin{array}{l} E(U_T'(1 - \theta)C''Ag'Ng - \\ U_T''((1 - \theta)(PAg' - C'Ag') - rA)((1 - \theta)(Pg - C'g) - rF - a)) \end{array}\right]}{S}. \tag{8}$$

We assume that the second order conditions for a maximum are satisfied.

In equation (2), the expression $E(U_R'(NPAg - C(NAg)))$ refers to the impact of a marginal increase in θ on the refiner's expected utility of profit. For a given amount of revenue being generated by the sale of refined beet sugar, an increase in θ will force up the refiner's profit in every state of nature and it follows that $E(U_R'((NPAg - C(NAg))) > 0$. At the same time, however, the farmers will respond to the change in θ by altering fertilizer use. In turn the refiner's profit must be affected by this secondary adjustment: $E(U_R'(\theta(NPAg' - C'NAg')\,F_\theta))$ characterizes this formally. Thus a marginal increase in θ will have both primary and secondary effects on the refiner. Unfortunately it is not possible to obtain a determinate sign for F_θ - at least for the case of a risk neutral refiner. Of course the farmers must also be affected, and the expression $- E(U'_T(NPAg - C(NAg)))/N$ shows how the individual farmer will be adversely affected by a marginal increase in θ. Thus when choosing the optimal value for θ, the refiner will equate the refiner's expected marginal utility of profit to the farmer's expected marginal disutility of income that is associated with a marginal change in θ.

It is possible to give a similar interpretation to equation (3). The expression $E(U'_R(1 + \theta(NPAg' - C'NAg') F_B))$ refers to the impact of a marginal increase in the revenue transfer (B) on the refiner's expected utility of profit. Once again the first component represents the direct influence, while the second allows for the induced change in fertilizer use. The adverse impact of the change on the farmer is given by $- E(U'_T)/N$. Thus the refiner will equate his expected marginal utility of profit to the farmer's expected marginal disutility of income from a change in B, when choosing B.

In choosing the optimal value for A, the refiner will realize that an increase in the individual farmer's contracted acreage will result in an increase in the revenue generated by the sale of refined beet sugar, and in the refiner's expected utility: $E(U'_R(\theta(NPg - C'Ng)))$. Also, an incentive effect comes into play since the increase in A will induce an adjustment in fertilizer use and therefore in the refiner's expected utility: $E(U'_R(\theta(NPAg' - C'NAg') F_A))$. The summation of these two terms gives the impact of a marginal increase in A on the refiner's expected welfare. Of course, the farmer's welfare will also be affected by the marginal change: $E(U_T^{\prime}((1 - \theta)(Pg - C'g) - rF - \bar{a}))$. And finally, in equilibrium the refiner's expected marginal utility of profit that is associated with an increase in A must equal the farmer's expected marginal disutility of income.

Equation (5) formalizes ~~the assumption~~ that the farmer's welfare must remain at some minimally acceptable level. Implicit in the set of first order conditions are the equilibrium values for θ, B, A, and F. Unfortunately it is not possible to actually solve the set of equations to obtain their values; as Hurwicz and Shapiro (1978) can with their simplified model. The reason being that our specification of the utility functions, production function, etc., is not sufficiently restrictive to permit the carrying out of that type of exercise.

Recall that the refiner will choose the characteristics of the contract, while knowing how the farmers will respond to the choice. The incentive effects indicate to the refiner how the farmer will react to any changes in θ, B, and A: that knowledge being crucial if the producers are to be induced to apply the 'correct' level of fertilizer. It follows that there are three separate incentive effects built into our model - F_θ, F_B, and F_A. They measure the endogenous variation in F associated with the refiner's understanding of the farmer's behavior.

It is self-evident that the direction of the various incentive effects will be of particular importance when setting the terms of the contract. Unfortunately, the expressions are of indeterminate sign unless additional restrictions are imposed on the model. To see this more clearly, let us examine the three cases separately. From the perspective of an individual farmer, B is analogous to a lump-sum tax or subsidy. Hence, a change in B would not be expected to lead to any alteration in fertilizer use. However, this argument ignores the fact that we are operating in a stochastic environment. A change in B will force an adjustment in the farmer's income for every possible state of nature. Given the risk aversion of the farmer, if this leads to an alteration in the 'risk' that he faces, fertilizer use will be adjusted. Let us try to make this argument more precise by defining $R_A^T = -U_T''/U_T'$ as the farmer's degree of absolute risk aversion. Thus

$$F_B = \frac{-E(R_A^T U_T'((1-\theta)(PAg' - C'Ag') - rA))/N}{S}$$

$$= \frac{-E(R_A^T)E(U_T'((1-\theta)(PAg' - C'Ag') - rA))/N}{S}$$

$$\frac{-Cov(R_A^T, U_T'((1-\theta)(PAg' - C'Ag') - rA))/N}{S}$$

$$= \frac{-Cov(R_A^T, U_T'((1-\theta)(PAg' - C'Ag') - rA))/N}{S}$$

Since $U_T'((1-\theta)(PAg' - C'Ag') - rA)$ is positively monotone with respect to $E(U_T'((1-\theta)(PAg' - C'Ag') - rA)) = 0$, it follows immediately that $F_B \lesseqgtr 0$ as $R_A^{T\prime} \lesseqgtr 0$.[7] The degree of absolute risk aversion corresponds to the odds that a risk averse individual requires if he is to be willing to accept a small bet of fixed size.[8] If R_A^T is a declining function of income, then an increase in B will force up the odds demanded. His response to this will be a reduction in fertilizer use.

If anything the incentive effect associated with changes in contracted acreage (A), is even more complicated than the one described above. From (8)

$$F_A = \frac{\left[\begin{array}{l} E(U_T'(1-\theta)C''Ag'Ng) + \\ Cov(R_A^T((1-\theta)(Pg - C'g) - rF - a), U_T'((1-\theta)(PAg' - C'Ag') - rA)) \end{array}\right]}{S}$$

We find that this incentive effect has two components: the first linked to whether the marginal costs of refining are increasing or decreasing, the second to the attitude toward risk of the farmer. Since, in general, the two components may be of opposite sign, obtaining a determinate sign for F_A is typically impossible. However, we do recognize that if $R_A^{T\prime} = 0$, then Cov(...,...) > 0 and $C'' \gtreqless 0$ is sufficient to guarantee that $F_A < 0$. Under the conditions specified above, the refiner could motivate the farmer to apply more fertilizer by cutting back on his contracted acreage.

The final incentive effect deals with changes in θ. From (6)

$$F_\theta = \frac{\left[\begin{array}{l} E(U_T'(PAg' - C'Ag')) - \\ \quad - Cov(R_A^T(NPAg - C(NAg))/N, U_T'((1-\theta)(PAg' - C'Ag') - rA)) \end{array}\right]}{S}$$

Once again we have two components to deal with. The first may be deemed the mean effect because it corresponds to the reduction in the expected marginal product of fertilizer to the farmer that is associated with an increase in θ. As is to be expected, it has a negative sign. The covariance term, on the other hand, follows from the risk aversion of the farmer. For instance, suppose that the farmer's degree of absolute risk aversion is increasing, then the 'risk aversion effect' will have a positive sign. The intuitive explanation for this result is straightforward. An increase in θ leads to a decrease in both the farmer's income, and the odds demanded. Since he has, in a sense, become less concerned with the inherent risk, his response will be an increase in fertilizer use. Bringing together the two parts of the argument, the sign of F_θ remains unknown because the mean effect and the risk aversion effect would force the refiner to adjust θ in opposite directions.

In summarizing the results of the previous three paragraphs, we found that the individual incentive effects were of indeterminate sign. Much of the analysis which follows will be concerned with how they interact in determining the characteristics of the contract.

Let

$$D_0 = NPAg(F) - C(NAg(F)), \text{ and}$$

$$D_1 = NPAg' - C'NAg';$$

then from (2) and (3)

$$\frac{E(U_R'D_0) + E(U_R'\theta D_1)\, F_\theta}{E(U_R') + E(U_R'\theta D_1)\, F_B} = \frac{E(U_T'D_0)}{E(U_T')} . \tag{9}$$

From (9)

$$E(U_T')E(U_R'D_0) + E(U_T')E(U_R'\theta D_1)\, F_\theta$$
$$= E(U_T'D_0)E(U_R') + E(U_T'D_0)E(U_R'\theta D_1)\, F_B,$$

hence

$$E(U_T'D_0)E(U_R') - E(U_T')E(U_R'D_0)$$
$$= E(U_T')E(U_R'\theta D_1)\, (F_\theta - (E(U_T'D_0)/E(U_T'))\, F_B) ,$$

or

$$\left[\frac{E(U_T'D_0)}{E(U_T')} - \frac{E(U_R'D_0)}{E(U_R')}\right] = \frac{E(U_R'\theta D_1)}{E(U_R')}\left[F_\theta - \frac{E(U_T'D_0)}{E(U_T')}\, F_B\right] . \tag{10}$$

Since the costs of obtaining the pure sugar from the beets - C(NAg) - is non-stochastic, (10) can be rewritten as

$$NAg\left[\frac{E(U_T'P)}{E(U_T')} - \frac{E(U_R'P)}{E(U_R')}\right] = \frac{E(U_R'\theta D_1)}{E(U_R')}\left[F_\theta - \frac{E(U_T'D_0)}{E(U_T')}F_B\right]. \tag{11}$$

We begin the process of analyzing the equilibrium by assuming that the refiner is risk neutral and the farmers are risk averse. Under these conditions, (11) may be rewritten as

$$NAg\left[\frac{E(U_T'P)}{E(U_T')} - E(P)\right] = \theta NAg'(E(P) - C')\left[F_\theta - \frac{E(U_T'D_0)}{E(U_T')}F_B\right]. \tag{12}$$

Clearly, (12) cannot be satisfied if $\theta = 0$. This follows because

$$\left[\frac{E(U_T'P)}{E(U_T')} - E(P)\right] = \frac{Cov(U_T', P)}{E(U_T')},$$

and if $\theta = 0$, the farmer's income is stochastic and $Cov(U_T', P) < 0$. Conversely, when $\theta = 1$ the left hand side of the equality must be set equal to zero. On the other hand,

$$\left[F_\theta - \frac{E(U_T'D_0)}{E(U_T')}F_B\right]\Bigg|_{\theta=1} = \frac{E(U_T'(PAg' - C'Ag'))}{(rA)^2E(U_T'')} < 0. \tag{13}$$

Bringing together the two arguments, we conclude that since both $\theta = 0$ and $\theta = 1$ are impossible, the contract involves sharecropping, i.e., $0 < \theta < 1$.[9] The combined impact of the incentive effects is easy to see. If they had cancelled one another — $(F_\theta - (E(U_T'D_0)/E(U_T'))\, F_B)$ — then

θ would equal one. It is because the overall incentive effect is negative, that θ is guaranteed to be less than unity. It turn, we can conclude that fertilizer will be applied to the crop, while this would not otherwise be true.[10]

RESULT 1: If the refiner is risk neutral and the farmers are risk averse, then $0 < \theta < 1$.

This result is interesting because it indicates the strength of the incentive effects. Normally we would argue that since our refiner is risk neutral, he should bear all of the risk associated with sugar beet farming; this is exactly what happens if the incentive effects cancel one another and θ equals one. In fact the risk neutrality of the refiner has been dominated by the refiner's understanding of the farmer's behavior pattern. As always, however, our primary concern must be in explaining the proportion of the net price that the farmers are to receive, that is

$$(1 - \theta) - \frac{B}{(P - C(NAg(F))/NAg(F))*NAg(F)}.$$

From RESULT 1, $0 < \theta < 1$ therefore the farmers are receiving a proportion of the refined sugar's net price. Whether that proportion is either constant or changing, depends on the sign of B. Below we address this issue.

We follow an indirect approach in attempting to sign B. According to the procedure, we begin with an equilibrium contract then eliminate the incentive effects, recognize that θ would tend to unity, and specify the concurrent change in B. Let us begin the process of formalizing this argument by rewriting equations (1) and (5), respectively, as $h(\theta,B,A,F,) = 0$ and $f(\theta,B,A,F) = 0$. Upon totally differentiating them, we obtain

$$h_\theta d\theta + h_B dB + h_A dA + h_F dF = 0, \text{ and}$$

$$f_\theta d\theta + f_B dB + f_A dA = 0; \text{ hence}$$ [11]

$$\begin{bmatrix} h_A & h_B \\ f_A & f_B \end{bmatrix} \begin{bmatrix} dA \\ dB \end{bmatrix} = \begin{bmatrix} -h_\theta d\theta - h_F dF \\ -f_\theta d\theta \end{bmatrix},$$

$$dB = \frac{(h_\theta f_A - h_A f_\theta)d\theta + h_F f_A dF}{(h_A f_B - h_B f_A)}, \text{ and}$$

$$\frac{dB}{d\theta} = \frac{\left[\frac{dF}{d\theta} + \frac{h_\theta}{h_F} - \frac{h_A}{h_F}\frac{f_\theta}{f_A}\right]}{\left[\frac{h_A}{h_F}\frac{f_B}{f_A} - \frac{h_B}{h_F}\right]}. \qquad (14)$$

The expression (h_θ/h_F) shows how the farmer would alter fertilizer use in response to a change in θ, i.e., $F_\theta = -h_\theta/h_F$. Similarly, $F_A = -h_A/h_F$ and $F_B = -h_B/h_F$. The interpretation that we give to the expression (f_θ/f_A) is also straightforward. f_θ measures the impact of a change in θ on the farmer's expected utility; f_A the impact of a change in A. It follows that (f_θ/f_A) shows the rate at which the farmer's share of net-revenue and acreage allotment can be substituted, while maintaining the farmer's expected utility at the constrained level; that is $\partial B/\partial A|_s = -f_A/f_B$, and $\partial A/\partial\theta|_s = -f_\theta/f_A$ (the subscript 's' is used to indicate a substitution effect). We may now rewrite $dB/d\theta$ as

$$\frac{dB}{d\theta} = \frac{\left[\frac{dF}{d\theta} - F_\theta - F_A \left.\frac{\partial A}{\partial \theta}\right|_s\right]}{\left[F_A \left.\frac{\partial A}{\partial B}\right|_s + F_B\right]} .$$

In general, obtaining a determinate sign for $dB/d\theta$ is impossible. To illustrate the problem, let us consider the following specific example: assume that $R_A^{T\prime} = 0$ and $C'' > 0$, then $F_B = 0$ and $F_A < 0$. Then

$$\frac{dB}{d\theta} = \frac{\left[\frac{dF}{d\theta} - F_\theta\right] - \left.\frac{\partial B}{\partial \theta}\right|_s}{\left[F_A \left.\frac{\partial A}{\partial B}\right|_s\right]} .$$

If $\partial B/\partial\theta|_s < 0$ and $\partial A/\partial B|_s < 0$, then there would be a tendency for B to be negative. Unfortunately, a definitive statement cannot be made until we can be assured as to the sign of $(dF/d\theta - F_\theta)$. A reasonable supposition would be that $(dF/d\theta - F_\theta) > 0$ – this just indicates the overall incentive effect has a more moderating influence than does F_θ by itself. If these conditions are met then $dB/d\theta > 0$: the incentive effects have induced a decrease in B (and since $B < 0$ when they are ignored) it follows that $B < 0$ in equilibrium. Of course this analysis does not permit us to draw any general conclusions because the actual values for F_θ, F_B, etc., are endogenous to our framework.

In summarizing this discussion, the sign of B is important because it allows us to determine whether the proportion of refined sugar's net price to be received by the farmers is either an increasing or decreasing function of the net price. Unfortunately our theoretical framework, at least in the case of a risk neutral refiner, sheds little light on this issue.

Let us now alter the situation, and assume that all the agents are risk averse. From (11)

$$NAg\left[\frac{Cov(U'_T,P)}{E(U'_T)} - \frac{Cov(U'_R,P)}{E(U'_R)}\right] = \frac{E(U'_R\theta D_1)}{E(U'_R)}\left[F_\theta - \frac{E(U'_T D_0)}{E(U'_T)}F_B\right]. \tag{15}$$

We recognize that $\theta = 0$ can be eliminated because $Cov(U'_R,P)$ would then equal zero while $Cov(U'_T,P)$ would be negative: it follows that the equality in (15) could not possibly be satisfied. Conversely, when $\theta = 1$ the expression on the left hand side of the equality would be positive, while $(F_\theta - (E(U'_T D_0)/E(U'_T)\ F_B)$ would then be negative. Hence, we conclude that $\theta = 1$ is impossible, and the contract involves sharecropping.

RESULT 2: If all individuals are risk averse, then $0 < \theta < 1$.

For reasons outlined previously, we would like to sign B. Of course, we could parallel the analysis which followed RESULT 1, but we would run into the same sort of problems. In fact, the situation would even be worse because with all individuals being risk averse, the sign of B is unknown even when the incentive effects are ignored. We recognize that restrictions must be imposed on the model if any results regarding B are to be obtained.

Suppose that all individuals have constant relative risk aversion utility functions. Thus

$$U_T(Y_T) = (Y_T)^{-m}/m, \text{ and } U_R(Y_R) = (Y_R)^{-v}/v,$$

where (1 + m) is the farmer's degree of relative risk aversion, and (1 + v) is the refiner's. Under this assumption, we may rewrite (11) as

$$NAg\left[\frac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} - \frac{E((Y_R)^{-v-1}P)}{E((Y_R)^{-v-1})}\right]$$
$$= \theta NAg' \frac{E((Y_R^*)^{-v-1}(P - C'))}{E((Y_R)^{-v-1})}\left[F_\theta - \frac{E((Y_T)^{-m-1}D_0)}{E((Y_T)^{-m-1})} F_B\right], \qquad (16)$$

where $F_B < 0$ and $F_\theta \gtrless 0$. Our demonstration as to whether $B \gtrless 0$ follows five steps. First, we observe the impact of a change in an individual's degree of relative risk aversion on his marginal rate of substitution between stochastic and deterministic profit. Next, we consider the same impact of changes in B, $\tilde{T}$, r, and a. And finally, the direction of the combined incentive effect is brought into play. By considering the various possibilities, we can determine whether $B \gtrless 0$ in equilibrium.[12]

STEP 1: Define

$$I = \frac{(Y_T)^{-m-1}}{E((Y_T)^{-m-1})}$$

then

$$I_m = \frac{-(Y_T)^{-m-1}\ln(Y_T)E((Y_T)^{-m-1}) + (Y_T)^{-m-1}E((Y_T)^{-m-1}\ln(Y_T))}{(E((Y_T)^{-m-1}))^2}$$

therefore

$$I_m \lessgtr 0 \quad \text{as} \quad \ln(Y_T) \gtrless \frac{E((Y_T)^{-m-1}\ln(Y_T))}{E((Y_T)^{-m-1})}.$$

Associated with a particular state of nature, there will exist a price (P^*) such that

$$\ln Y_T(P^*) = \frac{E((Y_T)^{-m-1}\ln(Y_T))}{E((Y_T)^{-m-1})},$$

then

$$\Phi_m \lesseqgtr 0 \text{ as } P \gtreqless P^*,$$

and

$$\frac{\partial\left[\dfrac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})}\right]}{\partial m} = \frac{\partial E(\Phi P)}{\partial m}$$

$$= E(P\Phi_m)$$

$$= E(\Phi_m(P - P^*))$$ [13]

$$< 0 .$$ [14]

Similarly

$$\frac{\partial\left[\dfrac{E((Y_R)^{-v-1}P)}{E((Y_R)^{-v-1})}\right]}{\partial v} < 0 .$$

STEP 2: Recall that

$$\Phi = \frac{(Y_T)^{-m-1}}{E((Y_T)^{-m-1})}$$

then

$$\Phi_r = \frac{E((Y_T)^{-m-1})(1 + m)(Y_T)^{-m-2}AF - (Y_T)^{-m-1}(1 + m)E((Y_T)^{-m-2})AF}{(E((Y_T)^{-m-1}))^2}$$

and $\Phi_r \gtreqless 0$ as $Y_T \lesseqgtr \dfrac{E((Y_T)^{-m-1})}{E((Y_T)^{-m-2})}$.

There will exist a price level ($\bar{P}$) such that

$$Y_T(\bar{P}) = \frac{E((Y_T)^{-m-1})}{E((Y_T)^{-m-2})},$$

then

$$\bar{I}_r \gtrless 0 \quad \text{as} \quad P \lessgtr \bar{P},$$

and

$$\frac{\partial \left[\dfrac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} \right]}{\partial r}$$

$$= E((P - \bar{P})\, \bar{I}_r)$$

$$< 0 .$$

By paralleling the analysis of STEP 2, the following results are obtainable:

STEP 3:

$$\frac{\partial \left[\dfrac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} \right]}{\partial a} < 0,$$

STEP 4:

$$\frac{\partial \left[\dfrac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} \right]}{\partial B} < 0,$$

$$\frac{\partial \left[\dfrac{E((Y_R)^{-v-1}P)}{E((Y_R)^{-v-1})} \right]}{\partial B} > 0, \text{ and}$$

STEP 5:

$$\frac{\partial \left[\dfrac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} \right]}{\partial \tilde{T}} > 0.$$

We begin the process of evaluating the expression on the left of the equality in (16) at the equilibrium levels of θ, A, and F, and at B = r = a = $\tilde{T}$ = 0. If the farmer's and refiner's degree of relative risk aversion were identical, then

$$\left[\frac{E((Y_T)^{-m-1}P)}{E((Y_T)^{-m-1})} - \frac{E((Y_R)^{-v-1}P)}{E((Y_R)^{-v-1})} \right] = 0. \qquad (17)$$

Starting from this position, STEP 1 indicates that an increase in the farmer's degree of relative risk aversion would force (17) to become strictly negative.

The analysis of STEPS 2 and 3 indicates that increases in the cost of fertilizer and the opportunity cost of land to their actual levels, will force further reductions in $E((Y_T)^{-m-1}P)/E((Y_T)^{-m-1})$, thereby exacerbating the inequality in (17). As STEPS 4 and 5 demonstrate, making B and $\tilde{T}$ positive would force an even greater divergence between the two terms in (17). That is

$$\frac{E((\tilde{T} + (1 - \theta)D_0/N - rAF - aA - B/N)^{-m-1}P)}{E((\tilde{T} + (1 - \theta)D_0/N - rAF - aA - B/N)^{-m-1})}$$

$$\leqq \frac{E((\tilde{T} + (1 - \theta)D_0/N - rAF - aA)^{-m-1}P)}{E((\tilde{T} + (1 - \theta)D_0/N - rAF - aA)^{-m-1})}$$

$$\leq \frac{E((D_0)^{-m-1}P)}{E((D_0)^{-m-1})}$$

$$< \frac{E((D_0)^{-v-1}P)}{E((D_0)^{-v-1})}$$

$$\leqq \frac{E((\theta D_0 + B)^{-v-1}P)}{E((\theta D_0 + B)^{-v-1})}$$

when $m > v$ and $B \geqq 0$. We conclude that the expression on the left of the equality in (16) will have a negative sign if $m > v$ and $B \geqq 0$.

In order to complete the analysis, we must evaluate the impacts of the two incentive effects - F_B and F_θ. Clearly, the movement of F_B to its actual level will tend to make the expression on the right hand side of the equality in (16) positive. This follows because $F_B < 0$ when the farmer's behavior toward risk is marked by constant relative risk aversion. On the other hand, since the sign of F_θ is unknown, we cannot be sure of the effect of this component of the incentive effect. Suppose, however, that $F_\theta > 0$, then $(F_\theta - ((E(Y_T)^{-m-1}D_0)/E((Y_T))^{-m-1}))F_B)$ will be positive. Upon bringing together the various parts of the argument, we conclude that a non-negative value for B is impossible; hence $B < 0$ when the farmers are more averse to risk than the refiner, and $F_\theta \geqq 0$.

RESULT 3: If all individuals have constant relative risk aversion utility functions, then $B < 0$ if the farmers have the higher degree of relative risk aversion, and $F_\theta \geqq 0$.

In discussing this result, let us recall that the sign of B is important for two reasons. First of all, the contractual arrangement al-

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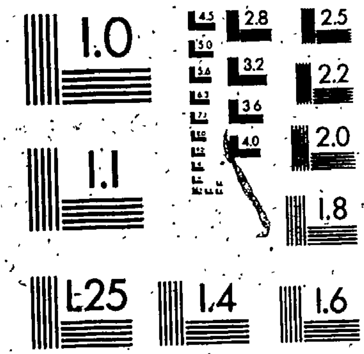


lows for a sharing of the profits generated by the sales of refined sugar, along with a revenue transfer between the refiner and the farmers. If B > 0 in equilibrium, then the contractual arrangement involves a combination of shared revenues and lump sum payment for the refiner. Similarly, if B < 0 then the farmers receive a lump sum payment. While this statement is correct, it does not recognize that the sign of B provides additional information. Following Stiglitz (1974), we treat the endogenous revenue transfer as being able to quantify the optimal degree of risk bearing. An increase in B must be associated with a reduction in θ in order to maintain the individual farmer's expected utility at the constrained level. If B > 0 then the farmer's income risk is increased relative to that when B = 0; correspondingly the refiner's profit risk must have decreased. We therefore say that when B > 0, the refiner is bearing a small proportion of the risk, and conversely for the farmers. Internal consistency is maintained because if B < 0 the refiner's risk increases while the farmer's declines. Relating this discussion back to RESULT 3, we find that - under the conditions specified - our refiner is bearing more of the risk associated with sugar beet farming that he would under 'pure' sharecropping - B = 0. Given that our farmers are, by assumption, more averse to risk than the refiner, this result is intuitive. The incentive effect associated with the share (F_θ) also plays a pivotal role. If F_θ equals zero, the refiner would choose a negative value for B, thereby inducing the farmers to apply more fertilizer to their land than they otherwise would. In turn the refiner's profit would be maximized. On the other hand, if F_θ was positive then θ would be increased in order to maximize the refiner's profits, with B remaining negative. It is only if the risk aversion of the farmers is overwhelmed by a negative incentive effect ($F_\theta < 0$) that B could be positive. Making the same point in a different way, it is natural for us to argue that the farmers are more averse to risk than the refiner. But the implication of this argument is for B to be negative. F_θ being negative acts as a counterbalancing force, and it is only if this incentive effect is strong enough to completely counteract the farmer's aversion towards risk, that B will be positive.

The second reason as to why the sign of B is important is because it allows us to discuss the relationship between the net price of sugar, and the proportion of the net price that the farmers are to receive. It should be clear, however, that this issue and our discussion of optimal risk sharing cannot logically be separated. For the farmers' proportion of the net price to be an increasing function of the net price, we require that $B > 0$. But given the farmers being more averse to risk than the refiner, B being positive is a possibility only if $F_\theta < 0$. It is unfortunate that our theoretical framework does not allow us to make a more definitive statement.

To this point in the analysis, we have been concerned with the terms of the payment scheme, and have neglected to consider the two remaining endogenous variables; contracted acreage, and fertilizer use. Below we discuss the impact of uncertain prices for refined sugar on factor use. With respect to fertilizer use, from (1)

$$(1 - \theta)E(U_T'(Pg' - C'g')) - rE(U_T') = 0, \text{ or}$$

$$(1 - \theta)E(U_T')E(Pg' - C'g') + Cov(U_T', (Pg' - C'g')(1 - \theta)) = rE(U_T'),$$

hence
$$(1 - \theta)(E(P)g' - C'g') = r - \frac{Cov(U_T', (Pg' - C'g')(1 - \theta))}{E(U_T')} . \quad (18)$$

From RESULTS 1 and 2, we know that $0 < \theta < 1$ and the income of the individual farmer is a random variable. It follows that

$$\mathrm{Cov}(U'_T, (Pg' - C'g')(1 - \theta)) < 0, \text{ and}$$

$$(1 - \theta)(E(P)g' - C'g') > r. \tag{19}$$

Thus the value of the expected marginal revenue product of fertilizer will, as expected, exceed its price.

In considering the issue of contracted acreage, from (3) and (4)

$$\frac{E(U'_R\theta N D_2) + E(U'_R\theta D_1)\ F_A}{E(U'_R) + E(U'_R\theta D_1)\ F_B}$$

$$= -\frac{E(U'_T((1 - \theta)D_2 - rF - a))N}{E(U'_T)}, \tag{20}$$

where $D_2 = Pg - C'g$. After some manipulation, (20) may be rewritten as

$$\frac{E(U'_T((1 - \theta)D_2 - rF - a))N}{E(U'_T)} + \frac{E(U'_R\theta D_2)N}{E(U'_R)}$$

$$= -\frac{E(U'_R\theta D_1)}{E(U'_R)}\left[F_A + \frac{E(U'_T((1 - \theta)D_2 - rF - a))\ F_B}{E(U'_T)}\right]$$

or

$$(E(P)g - C'g - rF - a)N$$

$$= -\frac{\mathrm{Cov}(U'_T, ((1 - \theta)D_2 - rF - a)N)}{E(U'_T)} - \frac{\mathrm{Cov}(U'_R, \theta D_2 N)}{E(U'_R)} \tag{21}$$

$$- \frac{E(U'_R\theta D_1)}{E(U'_R)}\left[F_A + \frac{E(U'_T((1 - \theta)D_\theta - rF - a))\ F_B}{E(U'_T)}\right].$$

Given the risk aversion of the farmers and $0 < \theta < 1$, we recognize that the covariances associated with farmer's marginal utility of income in (18) and (21) will be negative. Expressions of the type $\mathrm{Cov}(U_R', \ldots)$ in (21) will either equal zero or be negative, depending on whether the refiner is risk neutral or risk averse.

It follows from (18) and (21), that it is through the covariance terms and the overall incentive effect $- F_A + (*/* *)F_B$ – that 'risk' enters our framework. Hence, if we began with a situation where these expressions were assumed to equal zero, the farmers and refiner would be acting as if the price of refined sugar were known with certainty. If they were then re-introduced, there would be an alteration in contracted acreage and fertilizer use. Below we formalize this discussion and compare factor use under deterministic and stochastic conditions.

Let us rewrite equations (18) and (21), respectively, as

$$(E(P)g' - C'g') - r = e_1, \text{ and} \tag{22}$$

$$(E(P)g - C'g - rF - a)N = e_2 . \tag{23}$$

The terms e_1 and e_2 are used to indicate a movement from certain to risky conditions. We begin with both of them being equal to zero, then let them either increase or decrease as required, and observe the concurrent changes in F and A. From (22) and (23),

$$H_1 dF + H_2 dA = H_5 de_1, \text{ and}$$

$$H_3 dF + H_4 dA = H_6 de_1;$$

where

$$H_1 = (E(P)g'' - C'g'' - C''NA(g')^2) < 0,$$

$$H_2 = - C''Ngg' < 0 \text{ if } C'' > 0,$$

$H_3 = (E(P)g' - C'g' - C''NAgg' - r)N$,

$H_4 = - C''(Ng)^2 < 0$ if $C'' > 0$,

$H_5 = 1$, and

$H_6 = de_2/de_1$.

Then by Cramer's rule

$$\frac{\partial F}{\partial e_1} = \frac{\begin{vmatrix} H_5 & H_2 \\ H_6 & H_4 \end{vmatrix}}{\begin{vmatrix} H_1 & H_2 \\ H_3 & H_4 \end{vmatrix}} = \frac{H_5H_4 - H_2H_6}{H_1H_4 - H_2H_3}, \text{ and}$$

$$\frac{\partial A}{\partial e_1} = \frac{\begin{vmatrix} H_1 & H_5 \\ H_3 & H_6 \end{vmatrix}}{\begin{vmatrix} H_1 & H_2 \\ H_3 & H_4 \end{vmatrix}} = \frac{H_1H_6 - H_5H_3}{H_1H_4 - H_2H_3}.$$

It is easy to show that

$$H_1H_4 - H_2H_3 = C''N^2gg'((E(P)g' - C'g' - r) - (E(P) - C')g''g/g') > 0, \quad (24)$$

$$H_5H_4 - H_2H_6 = C''Ngg'(de_2/de_1) - C''(Ng)^2 , \quad (25)$$

and

$$H_1H_6 - H_5H_3 = H_1(de_2/de_1) - H_3. \quad (26)$$

$H_3 = (E(P)g' - C'g' - C''NAgg' - r)N$ measures the impact of an increase in fertilizer use on the expected marginal profit associated with an increase in contracted acreage: in general the sign of H_3 is unknown. Let us recall that e_1 and e_2 are used to indicate a movement from deterministic to risky conditions. From (18) and (22) it is clear that e_1 must become positive. On the other hand, we caan be assured that e_2 will become positive only if the overall incentive effect - F_A + (*/* *)F_B - is less than zero. It is possible, however, when evaluated at the stochastic equilibrium, (F_A + (*/* *)F_B) could be positive. If this effect is strong enough then in a movement to risky conditions, e_2 would become negative, i.e., $de_2/de_1 < 0$.

Suppose that we begin with a situation where the marginal profit associated with an increase in contracted acreage is unaffected by changes in the rate of fertilizer use ($H_3 = 0$), and the overall incentive effect is negative - which guarantees that $de_2/de_1 > 0$. From (25) and (26) it follows that $\partial A/\partial e_1 < 0$ while the sign of $\partial F/\partial e_1$ is unknown. The reduction in contracted acreage - in a movement from certain to risky conditions - is an expected result; not being able to immediately obtain a similar result vis-a-vis fertilizer use is somewhat surprising. The farmers would react to the introduction of risk, ceteris paribus, by cutting back on fertilizer use. However with a negative overall incentive effect, the farmers would react to the reduction in A by increasing fertilizer use. Under the conditions specified above, overall fertilizer use will decrease (increase) if the risk effect overwhelms (is overwhelmed by) the incentive effect. Making H_3 positive will not affect this conclusion. In fact, even if the overall incentive effect is positive this conclusion will follow so long as $de_2/de_1 > 0$. If, on the other hand, we begin with a situation where $de_2/de_1 < 0$ - which implies that the overall incentive effect is positive - and $H_3 \lesseqgtr 0$, then contracted acreage will increase and fertilizer use will fall. We summarize our results below.

RESULT 4: Let $g'' < 0$ and $\emptyset'' > 0$ then:

(i) $\partial F/\partial e_1 < 0$ if $de_2/de_1 < 0$.

(ii) $\partial F/\partial e_1 > 0$ only if $de_2/de_1 > 0$.

(iii) $\partial A/\partial e_1 > 0$ if $de_2/de_1 < 0$ and $H_3 < 0$.

(iv) $\partial A/\partial e_1 < 0$ if $de_2/de_1 > 0$ and $H_3 > 0$.

IV.3.2. Differing Subjective Probability Distributions

Typically the subjective probability distributions of the refiner and the farmers will differ. In this section we analyze the sugar beet contract when the two distributions differ in either their means or their variances. Recall that our refiner understands the decision process being used by the farmer in determining fertilizer use. That knowledge will then be used in the choice of contract structure. Immediately we run into the issue of just how cognizant the refiner is of the differences that exist between the two probability distributions. For the sake of simplicity, we assume that the refiner is perfectly aware of them. This assumption simplifies the problem by ensuring that the actual level of fertilizer will be identical to the refiner's prediction.[15]

STEP I: The Farmer's Problem

$$\max_{(F)} E(U_T(Y_T))$$

For a maximum, we require that

$$E(U_T'(Y_T)(1 - \theta)D_1/N - rA)) = 0. \tag{27}$$

This, along with the sufficiency condition, is identical to that which was obtained when the distributions were identical.

STEP II: The Refiner's Problem

$$\underset{(\theta,B,A,K)}{\text{Max}}\ V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

The first order conditions are given by

$$V_\theta = E(U_R'(D_0 + \theta D_1 F_\theta)) + KE(U_T'(-D_0/N)) = 0, \qquad (28)$$

$$V_B = E(U_R'(1 + \theta D_1 F_B)) + KE(U_T'(-1/N)) = 0, \qquad (29)$$

$$V_A = E(U_R'(\theta N D_2 + \theta D_1 F_A)) + KE(U_T'((1 - \theta)D_2 - rF - a)) = 0 \qquad (30)$$

and $V_K = E(U_T(Y_T)) - \bar{U}_T = 0;$ (31)

where F_B, F_θ, and F_A are given by equations (6), (7), and (8): it will be assumed that the second order conditions for a maximum are satisfied.

In general two probability distributions may differ in many ways. Fortunately, however, two obvious options present themselves: either the distributions differ in their means or their variances, ceteris paribus. Let us denote as $E_R(P)$ and $Var_R(P)$, and $E_T(P)$ and $Var_T(P)$, the expected price of refined sugar and the variance of that price for the refiner and farmers, respectively.

From (28) and (29),

$$NAg\left[\frac{Cov(U_T',P)}{E(U_T')} - \frac{Cov(U_R',P)}{E(U_R')}\right] + E_T(P) - E_R(P) = \frac{E(U_R'\theta D_1)}{E(U_R')}\left[F_\theta - \frac{E(U_T'D_0)}{E(U_T')}F_B\right]. \qquad (32)$$

Let us begin by considering the possibility of θ being equal to zero in equilibrium. Under these conditions (32) may be rewritten as

$$NAg\ Cov(U_T', P)/E(U_T') + E_T(P) - E_R(P)) = 0.$$

The covariance term is clearly negative hence it follows that $\theta = 0$ can be eliminated only if $E_T(P) \leq E_R(P)$. Conversely θ being equal to zero in equilibrium is a possibility only if $E_T(P) > E_R(P)$.

The second part of the analysis considers the possibility of θ being equal to one in equilibrium. The expression on the right hand side of the equality in (32) is negative, $Cov(U_T', P) = 0$, and $Cov(U_R', P) \leq 0$ (depending on whether the refiner is risk averse or risk neutral) when $\theta = 1$. It follows that $\theta = 1$ can be eliminated if $E_T(P) \geq E_R(P)$, and $\theta = 1$ is a possibility only if $E_T(P) < E_R(P)$.

RESULT 5: (i) If $\theta = 0$ then $E_T(P) > E_R(P)$.

(ii) If $\theta = 1$ then $E_T(P) < E_R(P)$.

(iii) $0 < \theta < 1$ when $Var_T(P) \neq Var_R(P)$.

The addition of differing probability distributions to the analysis has influenced the strength of the incentive effects. To see this, recall from RESULTS 1 and 2 that their existence is sufficient to guarantee that the net-revenue from the sale of refined sugar be shared, i.e., $0 < \theta < 1$. The possibility that $E_T(P) > E_R(P)$ reinforces this influence in that θ could, in fact, be driven all the way to zero. Making this point in a different way, the refiner's knowledge of the farmer's behavior pattern is sufficient to guarantee that the farmer receive a proportion of the net revenue. That the refiner knows $E_T(P) > E_R(P)$ will lead him to reduce θ even further. In fact, if the tendency is strong enough

θ could be driven all the way to zero, with the farmers absorbing all of the risk associated with the sale of refined sugar. In the case where $E_T(P) < E_R(P)$, on the other hand, the difference in probability distributions will act as a moderating influence. In fact, it is possible that θ could equal one with the incentive effects being countered perfectly.

As always, our primary concern must be in explaining the relationship that exists between the refined sugar's net price, and the proportion of the net price to be received by the farmers. Recall that when $0 < \theta < 1$, the farmers are receiving a proportion of the net price. And whether that proportion is either constant of changing, depends on the sign of B. We recognize, of course, that the sign of B is important for a second reason; it is able to quantify the optimal allocation of risk between the refiner and the farmers. As has been noted previously, if any results regarding the sign of B are to be obtained, we must impose certain restrictions on our model. Let us therefore parallel the analysis of Section IV.3.1., and assume that all individuals have constant (relative) risk aversion utility functions.

After rewriting (28) and (29) in the manner of (16), we find that if differing subjective probability distributions are introduced into the analysis $E((Y_T)^{-m-1}P)/E((Y_T)^{-m-1})$ and $E((Y_R)^{-v-1})/E((Y_R)^{-v-1})$ are the critical terms affected. Below we consider how a change in either mean or variance will alter these expressions.

Let

$$I = \frac{(Y_T)^{-m-1}}{E((Y_T)^{-m-1})} \quad \text{and } \tilde{P} = P + z.$$

An increase in z will result in an increase in the mean of the farmer's subjective probability distribution. Therefore

$$\mathbb{I}_z \lessgtr 0 \quad \text{as} \quad Y_T \lessgtr \frac{E((Y_T)^{-m-1})}{E((Y_T)^{-m-2})} .$$

Associated with a particular state of nature, there will exist a price ($\overset{*}{P}$) such that

$$Y_T(\overset{*}{P}) = \frac{E((Y_T)^{-m-1})}{E((Y_T)^{-m-2})} ,$$

then

$$\mathbb{I}_z \lessgtr 0 \text{ as } P \lessgtr \overset{*}{P},$$

and

$$\frac{\partial \left[\dfrac{E((Y_T)^{-m-1}\tilde{P})}{E((Y_T)^{-m-1})}\right]}{\partial z} = \frac{\partial E(\mathbb{I}\tilde{P})}{\partial z} + 1$$

$$= E(P\mathbb{I}_z) + 1$$

$$= E(\mathbb{I}_z(P - \overset{*}{P})) + 1$$

$$> 0 .$$

Similarly

$$\frac{\partial \left[\dfrac{E((Y_R)^{-v-1}\tilde{P})}{E((Y_R)^{-v-1})}\right]}{\partial z} > 0 .$$

Thus an increase in the mean of the relevant probability distribution will force an increase in each expression.

Recall that

$$\mathbb{I} = \frac{(Y_T)^{-m-1}}{E((Y_T)^{-m-1})} \quad \text{and let } \tilde{P} = eP + z.$$

An increase in e in conjunction with a counterbalancing change in z will result in a mean preserving spread in the farmer's subjective probability distribution. Therefore

$$Ɨ_e \gtrless 0 \text{ as } \frac{Y_T}{(P - E_T(P))} \gtrless \frac{E((Y_T)^{-m-1})}{E((Y_T)^{-m-2}(P - E_T(P)))}$$

Associated with a particular state of nature, there will exist a price ($\overset{*}{P}$) such that $Ɨ_e(\overset{*}{P}) = 0$.

Then

$$Ɨ_e \lessgtr 0 \text{ as } P \gtrless \overset{*}{P},$$

and

$$\frac{\partial\left[\dfrac{E((Y_T)^{-m-1}\tilde{P})}{E((Y_T)^{-m-1})}\right]}{\partial e} = \frac{\partial E(Ɨ\tilde{P})}{\partial e} + \frac{E(U_T^{\dagger}(P - E_T(P)))}{E(U_T^{\dagger})}$$

$$= E(\tilde{P}Ɨ_e) + E(U_T^{\dagger}(P - E_T(P)))/E(U_T^{\dagger})$$

$$= E(Ɨ_e(P - \overset{*}{P})) + E(U_T^{\dagger}(P - E_T(P)))/E(U_T^{\dagger})$$

$$< 0 .$$

Similarly

$$\frac{\partial\left[\dfrac{E((Y_R)^{-v-1}\tilde{P})}{E((Y_R)^{-v-1})}\right]}{\partial e} < 0 .$$

Thus an increase in the variance of the relevant probability distribution will force an decrease in each expression.

Paralleling the analysis of RESULT 3, we begin the process of characterizing the equilibrium contract by evaluating the expression on the left of the equality in (16) at the equilibrium levels of θ, A, and F, and where $B = r = a = \tilde{T} = 0$, $v = m$, $E_T(P) = E_R(P)$, and $Var_T(P) = Var_R(P)$.

Starting from this position, the analysis just completed indicates that if either $E_R(P) > E_T(P)$ or $Var_R(P) < Var_T(P)$ then (17) will become strictly negative. STEPS 1 through 5 indicate an increase in the farmers degree of relative risk aversion will exacerbate this difference, as will increases in the cost of fertilizer, the opportunity cost of land, and $\tilde{T}$ to their actual levels. It follows that $B < 0$ when the farmers are more averse to risk than the refiner and $F_\theta \geq 0$.

RESULT 6: If all individuals have constant (relative) risk aversion utility functions, then $B < 0$ if the farmers have the higher degree of relative risk aversion, $F_\theta \geq 0$, and either $E_R(P) > E_T(P)$ or $Var_R(P) < Var_T(P)$.

We find that under the conditions specified, our refiner is bearing more of the risk associated with the sale of refined sugar than he would if B equalled zero. This is to be expected since he is, by assumption, less averse to risk than the farmers. Also, we find that the farmers' proportion of the net price will be a decreasing function of the net price. Three factors lead to this counterfactual result. Firstly, our restriction that $F_\theta \geq 0$. This indicates that our refiner will maximize his profit by increasing θ beyond that level which would be chosen if the incentive effects were ignored. In turn, fertilizer use would increase. But these changes interact so as to leave the farmer's welfare below the constrained level, requiring that B be negative. If, on the other hand, F_θ was strictly negative, the argument would be reversed and there would be a 'tendency' for B to become positive. Of course, this tendency would have to be sufficiently strong to overwhelm the risk aversion of the farmers. The second factor relates to the refiner's aversion towards risk. If his degree of relative risk aversion increased, he would alter the terms of the payment scheme so as to make his profit less risky. This would entail a reduction in θ and an increase in B: if this effect is strong enough, B could become positive leaving the farmers with an increasing proportion of the net price. And finally, differences in the two probability distributions have an intensifying influence. That is, if $F_\theta > 0$ then $(E_R(P) - E_T(P))$ being positive would lead to a strengthening of the influence of the incentive effects, an increase in θ, and B being made even more negative. On the other hand, if $F_\theta < 0$ then there will be an increased tendency for B to be positive.

IV.4. Comparative Statics

We are interested in the impact of changes in the various exogenous variables on the level of fertilizer use, and on the terms of the contract. Let i represent an arbitrarily chosen exogenous variable. Ex ante, we realize that the difficulties that we face are substantial. Not only must our refiner predict the farmers' response to a change in i, he must alter the terms of the contract in the optimal manner. As we shall see below, modelling this type of behavior is difficult.

Recall that the refiner's problem is given by

$$\max_{(\theta,B,A,K)} V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T) ,$$

where $F = F(\theta,B,\hat{A},i)$ from (27). The first order conditions for a maximum may be written as

$$V_\theta = 0, \quad V_B = 0, \quad V_A = 0, \text{ and } V_K = 0.$$

Thus

$$\begin{bmatrix} V_{\theta\theta} & V_{\theta B} & V_{\theta A} & V_{\theta K} \\ V_{\theta B} & V_{BB} & V_{AB} & V_{BK} \\ V_{\theta A} & V_{AB} & V_{AA} & V_{AK} \\ V_{\theta K} & V_{BK} & V_{AK} & 0 \end{bmatrix} \begin{bmatrix} d\theta \\ dB \\ dA \\ dK \end{bmatrix} = - \begin{bmatrix} V_{\theta i} \\ V_{Bi} \\ V_{Ai} \\ V_{Ki} \end{bmatrix} di ,$$

or $$(\nabla_\theta \quad \nabla_B \quad \nabla_A \quad \nabla_K) \begin{bmatrix} d\theta \\ dB \\ dA \\ dK \end{bmatrix} = - \nabla_i \, di ,$$

where $$\nabla_x = \begin{bmatrix} V_{\theta x} \\ V_{Bx} \\ V_{Ax} \\ V_{Kx} \end{bmatrix}$$

After applying Cramer's rule, we find

$$\theta_i = \frac{- |\nabla_i \quad \nabla_B \quad \nabla_A \quad \nabla_K|}{|V|} ,$$

$$B_i = \frac{- |\nabla_\theta \quad \nabla_i \quad \nabla_A \quad \nabla_K|}{|V|} , \text{ and}$$

$$A_i = \frac{- |\nabla_\theta \quad \nabla_B \quad \nabla_i \quad \nabla_K|}{|V|} .$$

Each element in both the Hessian matrix (V) and ∇_i has two components: one associated with the direct impact of a change in i on θ, B, and A, ignoring any induced changes in F; the other due to the impact of a change in i on F, and therefore on θ, B, and A. For instance, if the farmer displays constant absolute risk aversion and the two probability distributions are identical, then

$$V_{\theta B} = E(U''_R(NPAg - C(NAg))) + KE(U''_T(NPAg - C(NAg)))/N^2 + E(U''_R\theta(NPAg' - C'NAg'))\, F_\theta$$

The expression $E(U''_R(\ldots)) + KE(U''_T(\ldots))/N^2$ is associated with the direct impact of a change in i on θ, B, and A - the alteration in F is ignored. On the other hand, $E(U''_R\theta(NPAg' - C'NAg'))\, F_\theta$ corresponds to the effect that a change in i has on F, and thence on θ, B, and A. In general, ~~we observe~~ observe

$$\nabla_i = D_i + E_i \ ,$$

where D_i (E_i) is the component of the Hessian matrix or ∇_i associated with direct (indirect) effect. Thus

$$\theta_i = \frac{-\,|D_i + E_i \quad D_B + E_B \quad D_A + E_A \quad D_K + E_K|}{|V|}, \tag{34}$$

$$B_i = \frac{-\,|D_\theta + E_\theta \quad D_i + E_i \quad D_A + E_A \quad D_K + E_K|}{|V|}, \text{ and} \tag{35}$$

$$A_i = \frac{-\,|D_\theta + E_\theta \quad D_B + E_B \quad D_i + E_i \quad D_K + E_K|}{|V|}. \tag{36}$$

Let us recognize that $E_K = (0)$: after manipulating (34)-(36) and applying this last result, we find

$$\theta_i = \frac{\begin{bmatrix} -\,|D_i \quad D_B \quad D_A \quad D_K| - |D \quad D_B \quad E_A \quad D_K| \\ -\,|D_i \quad E_B \quad \nabla_A \quad D_K| - |E_i \quad \nabla_B \quad \nabla_A \quad D_K| \end{bmatrix}}{|V|},$$

$$B_i = \frac{\begin{bmatrix} -|D_\theta \; D_i \; D_A \; D_K| - |D_\theta \; D_i \; E_A \; D_K| \\ -|D_\theta \; E_i \; V_A \; D_K| - |E_\theta \; V_i \; V_A \; D_K| \end{bmatrix}}{|V|}, \text{ and}$$

$$A_i = \frac{\begin{bmatrix} -|D_\theta \; D_B \; D_i \; D_K| - |D_\theta \; D_B \; E_i \; D_K| \\ -|D_\theta \; E_B \; V_i \; D_K| - |E_\theta \; V_B \; V_i \; D_K| \end{bmatrix}}{|V|}.$$

But

$$\theta_i\big|_{dF=0} = \frac{-|D_i \; D_B \; D_A \; D_K|}{|D|},$$

$$B_i\big|_{dF=0} = \frac{-|D_\theta \; D_i \; D_B \; D_K|}{|D|}, \text{ and}$$

$$A_i\big|_{dF=0} = \frac{-|D_\theta \; D_B \; D_i \; D_K|}{|D|},$$

hence,

$$\theta_i = \frac{|D| \; \theta_i\big|_{dF=0} - |D_i \; D_B \; E_A \; D_K| - |D_i \; E_B \; V_A \; D_K| - |E_i \; V_B \; V_A \; D_K|}{|V|},$$

$$B_i = \frac{|D| \; B_i\big|_{dF=0} - |D_\theta \; D_i \; E_A \; D_K| - |D_\theta \; E_i \; V_A \; D_K| - |E_\theta \; V_i \; V_A \; D_K|}{|V|},$$

and

$$A_i = \frac{|D| \; A_i\big|_{dF=0} - |D_\theta \; D_B \; E_i \; D_K| - |D_\theta \; E_B \; V_i \; D_K| - |E_\theta \; V_B \; V_i \; D_K|}{|V|}.$$

The last three equations formally recognize how the comparative static relationships can be broken down into direct and indirect effects. Unfortunately, it is not possible to carry the analysis forward and obtain determinate signs for θ_i, B_i, and A_i. It follows that we are unable to specify the change in fertilizer use associated with a movement in i, and more importantly, we cannot predict how the relationship that exists between the net price of the sugar that is sold and the proportion to be received by the farmers, is affected by exogenous variables. These issues are of particular concern to us, and it is because they have not been adequately dealt with here that we complete a simulation experiment in Chapter V. While it is clearly a second best choice, the simulation exercise will yield a great deal of insight into the relationship that exists between the refiner and the farmers.

IV.5. Concluding Remarks

In this chapter, the relationship that exists between the processor and producers of sugar beets has been analyzed. We recognized that both groups have variables they unilaterally control: the farmers, the actual production process; the refiner, the nature of the contract. After examing the problem in this manner, the applicability of the principal-agent paradigm was obvious. We followed it in modelling the producer-processor relationship, and found that individual attitudes toward risk, along with the characteristics of the random variable, were critical in determining the payment scheme.

The framework that we have developed and analyzed in this chapter makes traditional comparative static analysis impracticable. Since we are still interested in observing, for instance, the impact of a change in key exogenous variables, we are led to consider a simulation exercise for the system: this will be done in Chapter V. While the use of this technique does not permit any general results - in the theoretical sense

- it does yield a great deal of insight into how the system actually operates. As an example, we will be able to analyze the impact of a change in the farmer's attitude toward risk on the payment schedule; an exercise which would never be possible if we stayed within the general framework that we have chosen.

Endnotes

1. Output is measured in tonnes per acre, while fertilizer use is measured in pounds per acre.

2. Let $\tilde{P}$ = \$500.00/tonne be the futures market price for delivery at harvest, and let P be the spot price at harvest which is of course not known. Suppose that the farmer takes a short hedge at planting time. This means that he agrees to sell at price $\tilde{P}$ = \$500.00 for future delivery at harvest by buying on the futures market at price P_f. Since P_f is quoted on the New York sugar market, the price at delivery for an Alberta farmer may differ somewhat due to local market conditions and the fact that transportation costs represent a buffer between P and P_f. It is the difference $|P_f - P|$ which represents basis risk.

3. Let w equal the per acre opportunity cost of the farmer's labor that is applied to all farming activities; including the growing of sugar beets. Also, $\bar{A}$ represents the farmer's total land holdings, A the acreage seeded into sugar beets, $\bar{a}$ the cost per acre of using land (the costs of drainage, taxes, etc.), and $\tilde{a}$ the normal return per acre to the farmer as manager. Then:
$$Y_T = w\bar{A} + \tilde{a}\bar{A} + (1 - \theta)(NPAg(F) - C(NAg(F)))/N - B/N - rAF - (\bar{a} + \tilde{a} + w)A$$
Therefore $\tilde{T} = (w + \tilde{a})\bar{A}$ represents the normal income which accrues to the farmer, while the profit generated by sugar beet farming is given by
$(1 - \theta)(NPAg(F) - C(NAg(F)))/N - B/N - rAF - (\tilde{a} + \bar{a} + w)A$; where $a = (\tilde{a} + \bar{a} + w)$.

4. It will be dependent on other variables as well: for instance, the price of fertilizer.

5. Under risk neutrality, we obtain the exact Marshallian condition: $(1 - \theta)(E(P) - C')g' = r$.

6. The equations for F_θ, F_B, and F_A follow from implicit differentiation of (1).

7. See Scheffman (1975) for a discussion of these issues.

8. See Arrow (1974), p. 95.

9. A similar result is obtained by Berhold (1971), Hebert (1978), and Stiglitz (1974).

10. When θ = 1, the farmers are not receiving any part of the output generated by fertilizer's use. Hence, they will not apply any fertilizer to their crop.

11. f_F = 0 from (1).

12. The technique of proof used below was developed in Stiglitz (1974).

13. This follows since $\bar{P}$ is non-stochastic and $E(I_m) = 0$.

14. Whenever $P \gtrless \bar{P}$, $I_m \lessgtr 0$. Therefore $I_m (P - \bar{P}) \leq 0$, for every state of nature, and $E(I_m (P - \bar{P})) < 0$.

15. U_T represents what the refiner regards as the minimally acceptable level of welfare which must accrue to the farmers if they are to be induced to enter into a contract with the refiner. If the refiner makes a mistake in that the farmers actually require less, then the farmers return from sugar beet farming will be abnormally high when compared to that which can be obtained with other crops. In the latter case one would expect the refiner to revise his estimate of U_T upwards.

CHAPTER V

SIMULATION EXPERIMENT

V.1. Introduction

In Chapter IV, we attempted to give a detailed explanation of the forces which determine some of the parameters which characterize the contractual relationship that exists between the refiner and growers of sugar beets in western Canada (as well as input use by growers). Let us recall that the farmers' proportion of the net price is given by $((1 - \theta) - B/(NPAg(F) - C(NAg(F))))$. F represents per acre fertilizer use - its level being determined by the individual farmer. The contracted acreage of the individual farmer (A) and the terms of the payment scheme (θ and B), on the other hand, are chosen by the refiner. We used the term incentive effect to describe the impact of a marginal change in one of the terms of the contract on fertilizer use; it follows that there are three incentive effects built into our model since the refiner is fully cognizant of the farmers' decision making process, and how they would react to any changes in contractual terms. When choosing θ, B, and A he will take advantage of his knowledge regarding the magnitude of the three incentive effects, thereby inducing the farmers to apply that amount of fertilizer so as to leave his own welfare at a maximum. We found that the direction and magnitude of the three incentive effects, along with the attitudes toward risk of the refiner and farmers, were the crucial factors in determining the characteristics of the above relationship. Unfortunately, our analysis had several limitations associated with it. For instance, only if B > 0 will the relationship between the net price and the farmers' proportion be positive in nature:

we were unable to sign B when the refiner was risk neutral. Also, comparative static analysis turned out to be impracticable. Since we are still interested in observing the impact of changes in exogenous variables on the terms of the contract and fertilizer use, we complete a simulation exercise in this chapter. Clearly a second-best choice, this technique does not permit any general results in the theoretical sense. However, it will provide a great deal insight into the relationship that exists between the refiner and the farmers. In fact, certain questions may be raised which cannot be dealt with in the more general context. For instance, we may demonstrate how the terms of the contract and fertilizer use respond to a change in the refiner's degree of risk aversion.

The procedure that we follow is straightforward: i) first a set of model parameters are chosen so that the initial solution reproduces the contract which is currently observed; ii) then re-solve the problem (find the new values for the endogenous variables) for new hypothetical values for the main exogenous variables. It is by altering several of the key exogenous variables, that we will gain some insight into the way in which the various forces interact in determining the terms of the sugar beet contract.

In Section 2, we specify the utility and probability density functions for our individuals which subsequently are used to generate the first order conditions that characterize the sugar beet contract and fertilizer use. Section 3 discusses the procedure used to calibrate the model, while in Sections 4 and 5 we discuss the results of the experiment, for both a risk neutral and a risk averse refiner. Finally, some concluding remarks are made in Section 6.

V.2. Format of the Exercise

It is self-evident that the choice of format for the individual's utility functions and the probability density function for the random variable, will be crucial if the problem is to be made tractable. We follow Sutinen (1975) and assume that if risk averse, an individual has a constant absolute risk aversion utility function. Thus

$$U_R(Y_R) = - \mathrm{Exp}(-\overset{*}{u}Y_R), \text{ and}$$

$$U_T(Y_T) = - \mathrm{Exp}(-\overset{*}{v}Y_T);$$

where

$\overset{*}{u}$ = the refiner's degree of absolute risk aversion, and

$\overset{*}{v}$ = the farmer's degree of absolute risk aversion.

We treat the random variable (P) as following the Gamma probability distribution. This choice is made for two reasons. First, it allows us to consider mean preserving spreads in the distribution of P, and vice-versa. We recall that this will permit us to follow Rothschild and Stiglitz's definition[1] of a change in riskiness. Also, the exponential form of this distribution's probability density function simplifies the mathematics considerably. Let $(f_R(P)/f_T(P))$ represent the (refiner's/farmer's) subjective probability distribution of P, where

$$f_R(P) = \frac{W^q P^{q-1} e^{-WP}}{J(q)},$$

$$f_T(P) = \frac{G^j P^{j-1} e^{-GP}}{J(j)}, \text{ and}$$

$$J(x) = \int_0^\infty \exp(-P) P^{x-1} dP .$$

It may be shown[2] that the first two moments of the distributions are completely specified by the parameters q, j, W, and G, where

$E_R(P) = q/W$,

$E_T(P) = j/G$,

$Var_R(P) = q/W^2$, and

$Var_T(P) = j/G^2$,

then

$$E(U_R(Y_R)) = \int_0^\infty U_R(Y_R) f_R(P) dP$$

$$= \int_0^\infty \frac{(-\exp(-\overset{*}{u}Y_R)) W^q P^{q-1} e^{-WP} dP}{J(q)}$$

$$= -\frac{W^q}{J(q)} \int_0^\infty \exp(-\overset{*}{u}Y_R) P^{q-1} e^{-WP} dP. \quad (1)$$

Recall that

$$Y_R = \theta(NPAg - C(NAg)) + B \quad (2)$$

= the refiner's profit,

where

θ = proportion of the profits from the sale of refined sugar that is received by the refiner (with the rest going to the farmers),

B = revenue transfer between the refiner and the farmers,

N = number of identical farmers,

A = number of acres seeded into beets by the individual farmer,

F = amount of fertilizer to be applied per acre,

$g(F) = K_1 F^m$,

= output per acre as a function of fertilizer use,

P = price per tonne of refined sugar net of delivery charges (ex post), and

$$C(NAg(F)) = C_1(NAg(F))^2 + C_2(NAg(F)) + C_3$$

= cost of processing the beets into refined sugar.

Upon substituting (2) into (1), we obtain

$$E(U_R(Y_R)) = -\frac{W^q \exp(-\overset{*}{u}(B-\theta C(NAg)))}{J(q)} \int_0^\infty \exp(-\overset{*}{u}\theta NPAg)P^{q-1}\exp(-WP)dP$$

$$= -\frac{W^q \exp((-\overset{*}{u}(B-\theta C))}{J(q)} \int_0^\infty \exp(-(\overset{*}{u}\theta NPAg + WP))P^{q-1}dP.$$

Let $\overset{*}{P} = P(\overset{*}{u}\theta NAg + W)$ then $d\overset{*}{P} = dP(\overset{*}{u}\theta NAg + W)$ and

$$E(U_R(Y_R)) = -\frac{W^q \exp(-\overset{*}{u}(B-\theta C))}{J(q)(\overset{*}{u}\theta NAg + W)^q} \int_0^\infty \exp(-\overset{*}{P})\overset{*}{P}^{q-1}d\overset{*}{P}.$$

But $\int_0^\infty \exp(-\overset{*}{P})\overset{*}{P}^{q-1}d\overset{*}{P} = J(q)$ by definition, therefore

$$E(U_R(Y_R)) = -\frac{W^q \exp(-\overset{*}{u}(B-C(NAg))}{(\overset{*}{u}\theta NAg + W)^q}. \quad (3)$$

Similarly, we may show that

$$E(U_T(Y_T)) = -\frac{G^j \exp((\overset{*}{v}(B/N + (1-\theta)C(NAg)/N + rAF + aA - \tilde{T}))}{(\overset{*}{v}(1-\theta)Ag + G)^j}. \quad (4)$$

where

a = cost per acre of using land in the production of beets,

r = cost per pound of fertilizer,

Y_T = the individual farmer's profit,

$\tilde{T}$ = the normal return accruing to the farmer as manager and as a laborer on his own farm.[3]

Equation (3) specifies the refiner's expected utility of profit in terms of endogenous variables and parameters when he is risk averse. Conversely, when risk neutral, attention will be focused on his expected profit; where $E(Y_R) = \theta(NAg(F)q/W - C(NAg(F))) + B$.

As in Chapter IV, given the payment scheme and contracted acreage, the farmer will choose that level of fertilizer use so as to maximize $E(U_T(Y_T))$. When choosing the terms of the contract (θ, B, and A), the refiner will take advantage of his knowledge regarding the farmers' decision making process. But if the individual farmer is to be motivated to enter into the contract, he must be adequately reimbursed. Thus when the refiner is risk averse, his problem may be written as

$$\max_{(\theta,B,A,K)} V = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

where K = the Lagrange multiplier, $E(U_R(Y_R))$ and $E(U_T(Y_T))$ are given by (3) and (4), respectively, and

$\bar{U}_T$ = the minimum acceptable level of utility required by the farmer.[4]

V.3. Calibration Procedure

The two maximization procedures outlined above yield four simultaneous non-linear equations. The process of calibration involves choosing parameter values for the system so that the actual values for θ, B, A, and F will satisfy the set of first order conditions. Our approach in carrying out this exercise is straightforward. There are certain parameters which we have hard information on; whenever this information is available it is used in the process of calibration. On the other hand, for those parameters whose magnitudes are unknown, we choose values for them which, in turn, satisfy the constraint noted above. Once this operation is completed the "use of the model allows comparison between a historical equilibrium generated by existing policies which is assumed to be observable, and a hypothetical or counterfactual equilibrium which the model produces under a changed policy regime."[5] Given the discussion of Chapter IV, of particular interest to us would be changes in the attitude toward risk of the farmers and the refiner, respectively, along with adjustments in the nature of the subjective probability distribution over the price of refined sugar.

There are two sources of information regarding the economics of sugar beet production in southern Alberta. In 1975 the Beet Grower's Association requested that the Alberta Department of Agriculture carry out a cost of production study for the sugar beet industry. Forty farmers were chosen from the various beet growing areas, and submitted records of their operations for a three year period.[6] Most of the 'hard' information available to us was from this study. The yearly reports of the Beet Grower's Association were our only other source of information.

In our theoretical framework, there are only two factors of production, land and fertilizer: in reality, however, the actual list is quite lengthy. In deciding whether a factor of production is 'fixed' or 'variable', we use the following convention. If a factor's rate of use is independent of the crop being grown, it is included under the umbrella heading of land, i.e., fixed factors are those which are 'tied' to the land itself. Thus fixed costs include machine 'non-cash' costs, cash overhead, and non-cash overhead. Included under the first component would be depreciation charges, interest on investment, insurance, and an allowance for housing equipment used in sugar beet production.

Cash overhead includes land and water taxes, and interest on operating capital. Finally, non-cash overhead includes interest payments of investment in land and buildings, depreciation charges on housing facilities and machine shops, and construction costs for the building of roads and ditches. On the other hand, in our simulation experiment we use fertilizer to 'summarize' the influences of the variable (non-land) factors of production. For instance, labor is hired on both a contract and an hourly basis, while the farmer's own labor must be valued at it's opportunity cost. Machine 'cash' costs and material costs are also important. The former includes the cost of fuel, lubrication, and repairs to farm equipment; while the latter summarizes seed, fertilizer, and chemical costs.

Before beginning the formal process of calibration, the production, utility, and cost of refining functions must first of all be given specific functional forms. As Mansur and Whalley recognize "the choice of functional forms ... is guided in practice by the restrictions which ease of solution impose."[7] That is, the specific forms are chosen in order to make the problem tractable. It is for this reason that we let $g(F) = K_1F^m$ and $C(NAg(F)) = C_1(NAg(F))^2 + C_2(NAg(F)) + C_3$.

In specifying the utility functions for the farmers and refiner, we choose constant absolute risk aversion utility functions, i.e., $U_R(Y_R) = -\operatorname{Exp}(-\overset{*}{u}Y_R)$ and $U_T(Y_T) = -\operatorname{Exp}(-\overset{*}{v}Y_T)$. This selection is made for two reasons. First of all, the first order conditions from the two maximization procedures are substantially easier to deal with than they otherwise would have been. And second, being able to consider how a change in the farmer's degree of absolute risk aversion, for instance, will affect the contract is of particular concern to us.

The final functional relationships to be specified are the random variable's subjective probability distribution for both the farmers and the refiner. Given the risk sharing attributes of the contract, we are interested in observing how its terms will be adjusted in response to a change in riskiness - a mean preserving spread of the distribution. Therefore in choosing a particular subjective probability distribution we limit ourselves to choosing one which will make the above exercise straightforward. Also, in specifying the expected utility of one of our agents it is necessary to integrate the utility function over the range of prices, with the subjective probability distribution as a weighting factor - see Section V.2. for a specific example. If this integral is to be solved then both the utility function and the subjective probability distribution have to be chosen very carefully. Let us recall that the utility functions that we have chosen are exponential in nature. It follows that if we wish the integral to have a straightforward solution, choosing a probability distribution with an exponential form is appropriate. For the reasons outlined above, we treat the random variable (P) as following the Gamma probability distribution.

Let us recall that according to our theoretical framework, the farmer will choose the amount of fertilizer (F) to be applied per acre so as to maximize his expected utility of income, while taking the terms of the contract (θ, B, and A) as given. The refiner, on the other hand, will choose contractual terms so as to maximize his own expected welfare, while maintaining the farmer's (but from the refiner's perspective) at some minimally acceptable level (U_T). We assume that the level of welfare accruing to the individual farmer if he uses his land, labor, and managerial talents in the production of sugar beets will correspond precisely to that level if these inputs were applied to their best alternative use. It follows that as part of the calibration process it is legitimate for us to set $\bar{U}_T$ equal to the equilibrium value for $E(U_T(Y_T))$.[8]

Summarizing our discussion to this point, we recognize that involved in the process of calibration must be the specification of the production function (2 parameters), the cost of refining relationship (3 parameters), the utility functions (2 parameters), the probability distributions (2 parameters since at the benchmark solution we assume q=j and W=G), the costs of land and fertilizer (2 parameters), the return accruing to the farmer both as manager and as a laborer, and $\bar{U}_T$ - 13 coefficients must be given specific values. In carrying through with this procedure, the terms of the contract (θ, B, and A) and fertilizer use (F) are treated as exogenous variables, with the computer being used to generate values for a subset of four of these coefficients. The thirteen coefficients which characterize the sugar beet industry fall into one of two categories. First of all, those whose values we <u>estimate</u> given the information available: the costs of land and fertilizer (a and r), and return accruing to the farmer both as manager and from his work as a laborer on his own farm ($\tilde{T}$) fall under this heading. Second, those whose values we <u>specify</u> - this list includes the refiner's degree of absolute risk aversion ($\overset{*}{u}$), the parameters which characterize the production and cost of refining relationships (K_1, m, C_1, C_2, and C_3), the coefficients which characterize the subjective probability distributions (q=j and W=G), the farmer's degree of absolute risk aversion ($\overset{*}{v}$), and the farmer's minimally acceptable level of welfare ($\bar{U}_T$).

When choosing the parameters which characterize the cost of refining and production relationships - $C(NAg) = C_1(NAg)^2 + C_2(NAg) + C_3$ and $g(F) = K_1F^m$ - several constraints have to be satisfied. For instance, the production function's input elasticity (m) has to be set at a value consistent with those which have been observed in the agricultural sector. Second, while the production of refined sugar per acre - g(F) - changes on a year-to-year basis, approximately 2.1 tonnes of refined sugar are typically produced per acre. In other words, when choosing specific values for K_1 and m we must guarantee that they interact in such a way so as leave the production of refined sugar per acre at the actual level.

Similar issues arise when we consider the specification of the parameters which characterize the cost of refining function (C_1, C_2, and C_3). Values for the three of them have to be chosen so that refining costs per tonne correspond to estimated levels. To this point we have been concerned with choosing specific values for K_1, m, C_1, C_2, and C_3 so that several constraints are satisfied. The final issue involves specifying a particular value the refiner's degree of absolute risk aversion ($\overset{*}{u}$). After these initial estimates are made, the computer is then used to solve for the values for j=q, W=G, and $\overset{*}{v}$ which satisfy a subset of three of the first order conditions: this follows because U_T enters only one of them. Once the computer algorithm has converged, the specific values for all the coefficients and the actual values for θ, B, A, and F are then substituted into $E(U_T(Y_T))$, and U_T is determined. However, the process of calibration is not necessarily complete because for the results to be intuitive the refiner must be less averse to risk than the individual farmer, i.e., $\overset{*}{u} < \overset{*}{v}$. Similarly, the values which

TABLE V-A

THE SPECIFICATION OF PARAMETER VALUES

ESTIMATED	SET EXOGENOUSLY	DETERMINED WITHIN THE COMPUTER ALGORITHM SO AS TO SATISFY THE SET OF FIRST ORDER CONDITIONS	PARAMETER
*			a
*			r
*			$\tilde{T}$
	*		C_1
	*		C_2
	*		C_3
	*		K_1
	*		m
	*		u^*
		*	$q=j$
		*	$W=G$
		*	v^*
		*	U_T

are generated by the computer for q=j and W=G must leave the expected price for refined sugar in the range which has been observed for the last few years. If these conditions are not met then it is necessary to alter the values for the coefficients until all of the side constraints are satisfied.

In Section V.4. we will report how the predicted contract is affected by changes in the characteristics of the probability distributions, and the farmer's and refiner's attitudes toward risk. Our results are summarized in two forms. In Tables V-B-1 and V-B-2, the specific values for the risk aversion and probability distribution parameters are given which yield a benchmark solution,[9] i.e., those which yield a generated contract which is identical to the actual one. Thereafter, these parameters are changed and the new values for the terms of the contract (θ, B, and A) and fertilizer use (F) are reported; with the elasticities being specified immediately below.[10] These results are then given a geometrical interpretation in the figures which follow the two tables. In the 8 figures, we relate changes in the farmers' share to the net price. In general, reductions in both θ and B will lead to increases in the farmers' proportion of the net price, i.e., to a positive change in their share. In conjunction with these movements, B's value is also positively related to the lines slope.

V.4. Results of the Analysis[11]

Chapter IV made it quite clear that three factors interact in determining the characteristics of the relationship that exists between the net price received for the refined sugar, and the farmers' receipts. First of all, the nature of the subjective probability distributions over the price of refined sugar for the refiner and farmers, respectively. Second, their attitudes toward risk. And finally, since the refiner is aware of the procedure used by the farmers in making decisions, it follows that when setting the terms of the contract, he would account for the incentive effects. Of course we cannot carry out a comparative static exercise and alter them as if they were parameters, since both their magnitude and direction are determined endogenously. If follows that we can only consider how changes in the first two sets of factors will affect the sugar beet contract that is predicted in the simulation. In Tables V-B-1 and V-B-2, we summarize our results then depict them geometrically in Figures V-A through V-H.

As our first exercise, let us consider a mean preserving spread in the farmer's subjective probability distribution. Row 4 reports the induced changes in the terms of the contract and in fertilizer use, while Figure V-C illustrates how these changes interact in altering the predicted relationship between the price of refined sugar and the farmers' share. The impact effect of an increase in the farmer's perceived variance in the distribution of prices is a decrease in fertilizer use. This follows because the change would force a reduction in the farmer's marginal revenue product of fertilizer (in utility terms), and the farmers could therefore increase their expected utility by cutting back on fertilizer use. Of course this adjustment will adversely affect the refiner's welfare (or his expected profit in the case of a risk neutral refiner), and he will therefore alter the terms of the contract in order to mitigate the adverse welfare effects of the change. This will be accomplished by reducing both θ and A (increasing θ and reducing A) when the refiner is risk neutral (averse). Subsequently, the farmers will react to these last changes by increasing fertilizer use, i.e., the sec-

TABLE V-B-1

THE EFFECTS OF CHANGES IN THE KEY EXOGENOUS VARIABLES:

THE CASE OF A RISK AVERSE REFINER

θ	B	A	F	q	W	j	G	v*	u*	Fig.
0.37	0.0	51.2	225.0	3447.2	5.4	3447.2	5.4	0.08	0.000073	
0.370 -0.00	-168985.5 (-)	43.0 -0.99	224.9 -0.00	2888.0	5.0	2888.0	5.0	0.08	0.000073	V-A
0.357 -0.21	503454.1 (+)	48.9 -0.26	237.2 0.30	2888.0	5.0	3447.2	5.4	0.08	0.000073	V-B
0.382 0.18	-572102.3 (-)	44.9 -0.74	214.0 -0.28	3447.2	5.4	2888.0	5.0	0.08	0.000073	V-C
0.398 0.67	827048.1 (+)	71.5 2.99	215.9 -0.37	4301.5	6.0	4301.5	6.0	0.08	0.000073	V-D
0.404 0.80	-1516869.8 (-)	58.6 1.22	193.2 -1.38	4301.5	6.0	3447.2	5.4	0.08	0.000073	V-E
0.359 -0.27	2816795.8 (+)	62.8 1.85	250.4 0.97	3447.2	5.4	4301.5	6.0	0.08	0.000073	V-F
0.375 0.18	-279412.1 (-)	48.3 -0.74	220.0 -0.29	3447.2	5.4	3447.2	5.4	0.09	0.000073	V-G
0.306 -0.27	2147175.8 (+)	42.2 -0.28	282.7 0.32	3447.2	5.4	3447.2	5.4	0.08	0.000150	V-H

TABLE V-B-2

THE EFFECTS OF CHANGES IN THE KEY EXOGENOUS VARIABLES:

THE CASE OF A RISK NEUTRAL REFINER

θ	B	A	F	q	W	j	G	v^*	Fig.
0.37	0.0	51.2	225.0	10010.3	17.6	10010.3	17.6	0.17	
0.370 -0.00	-20151.9 (-)	49.4 -1.00	225.1 0.01	9654.6	17.0	9654.6	17.0	0.17	V-A
0.37 0	0 (0)	51.2 0	225.0 0	9654.6	17.0	10010.3	17.6	0.17	V-B
0.370 -0.00	-20151.9 (-)	49.4 -1.00	225.1 0.01	10010.3	17.6	9654.6	17.0	0.17	V-C
0.377 0.91	149357.3 (+)	54.0 2.58	225.5 0.11	10439.2	18.0	10439.2	18.0	0.17	V-D
0.380 1.31	-414274.6 (-)	53.4 2.01	214.9 -2.19	10439.2	18.0	10010.3	17.6	0.17	V-E
0.367 -0.41	568989.0 (+)	51.8 0.60	236.0 2.28	10010.3	17.6	10439.2	18.0	0.17	V-F
0.371 0.03	-87249.4 (-)	48.6 -0.85	223.3 -0.12	10010.3	17.6	10010.3	17.6	0.18	V-G

FIGURE V-A

THE IMPACT OF AN INCREASE IN THE VARIANCE OF THE TWO INDIVIDUALS' PROBABILITY DISTRIBUTIONS ON THE PREDICTED CONTRACT

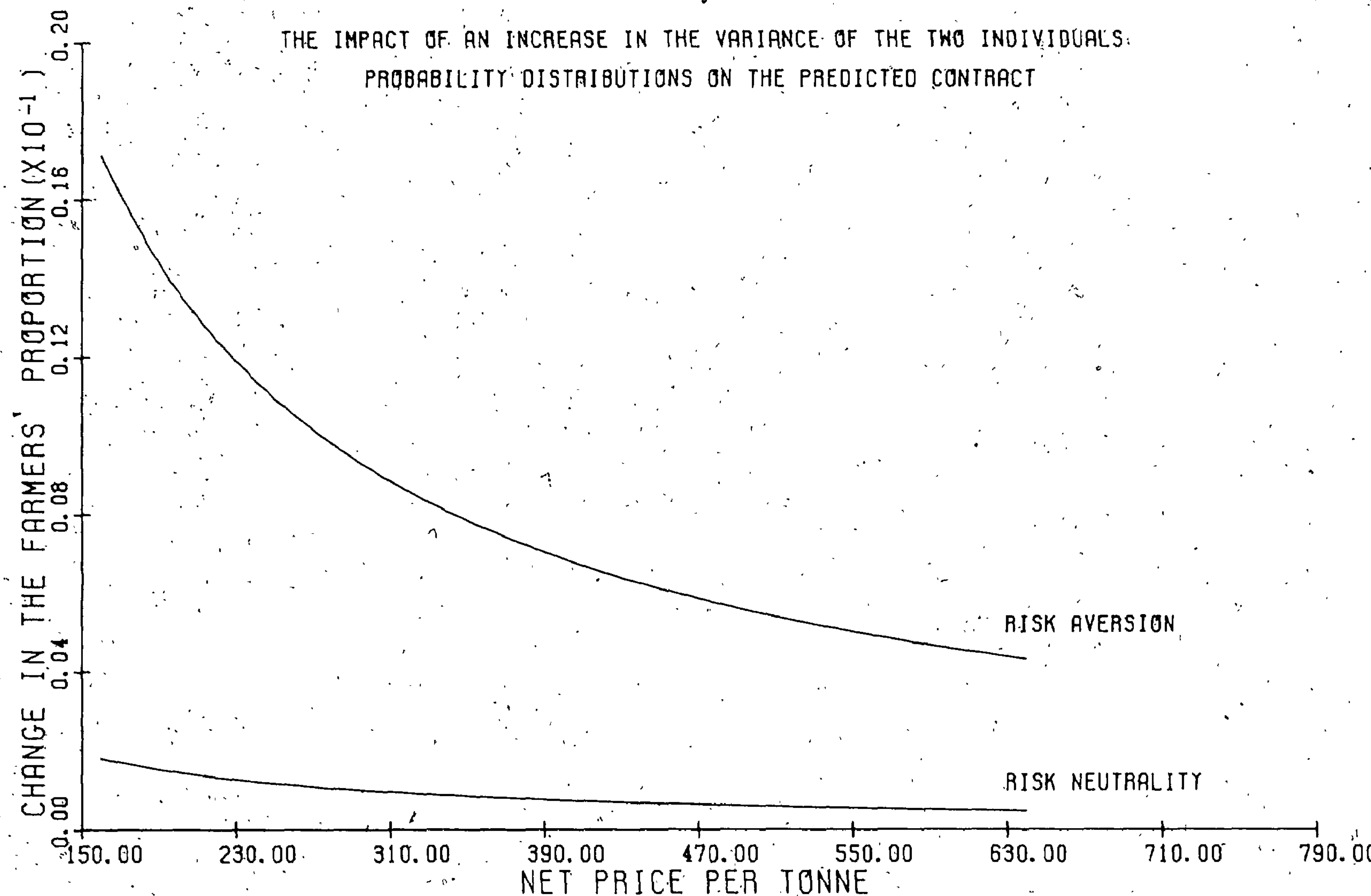


FIGURE V-B

THE IMPACT OF AN INCREASE IN THE VARIANCE OF THE REFINER'S PROBABILITY DISTRIBUTION ON THE PREDICTED CONTRACT

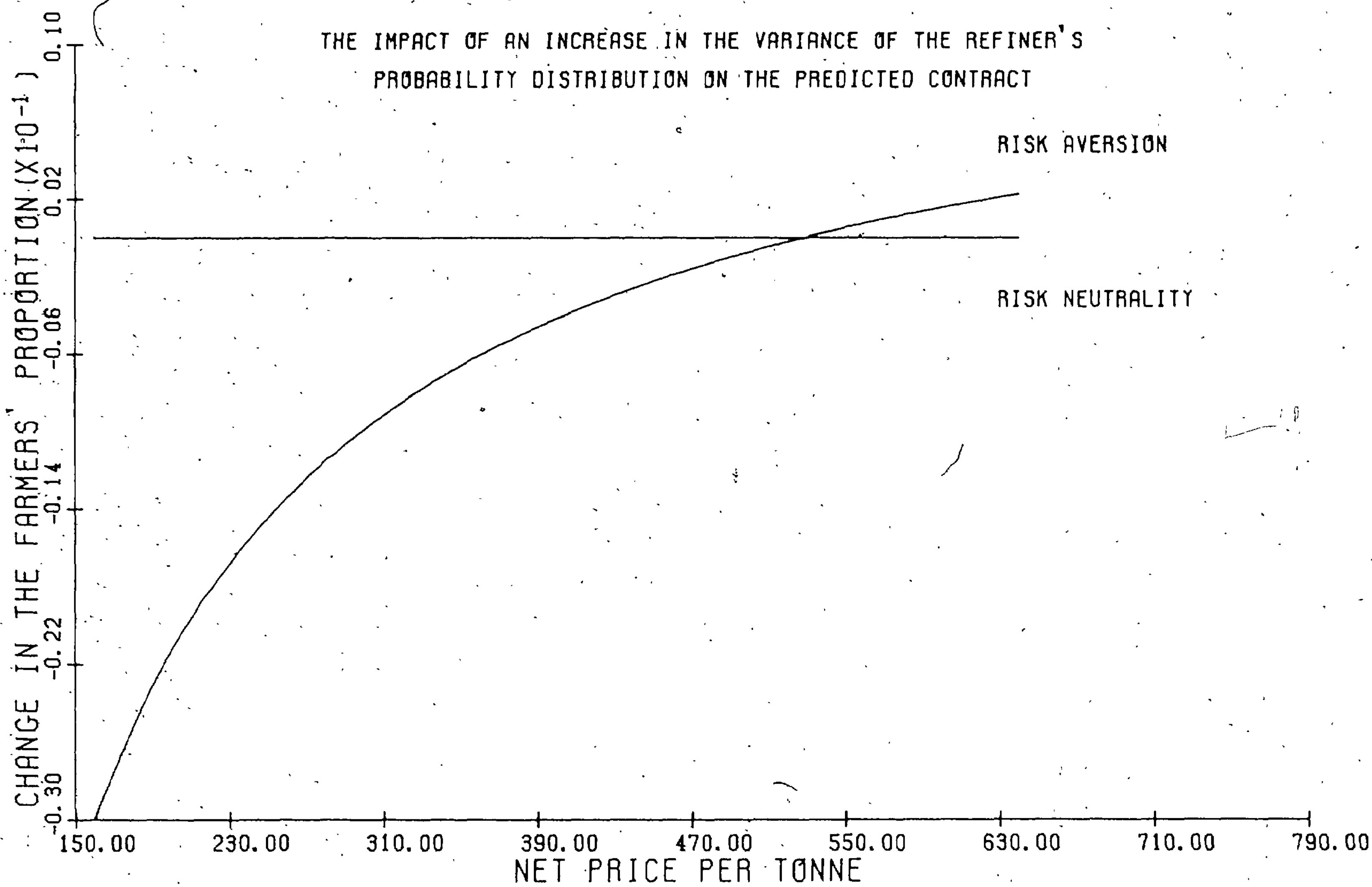


FIGURE V-C

THE IMPACT OF AN INCREASE IN THE VARIANCE OF THE FARMER'S PROBABILITY DISTRIBUTION ON THE PREDICTED CONTRACT

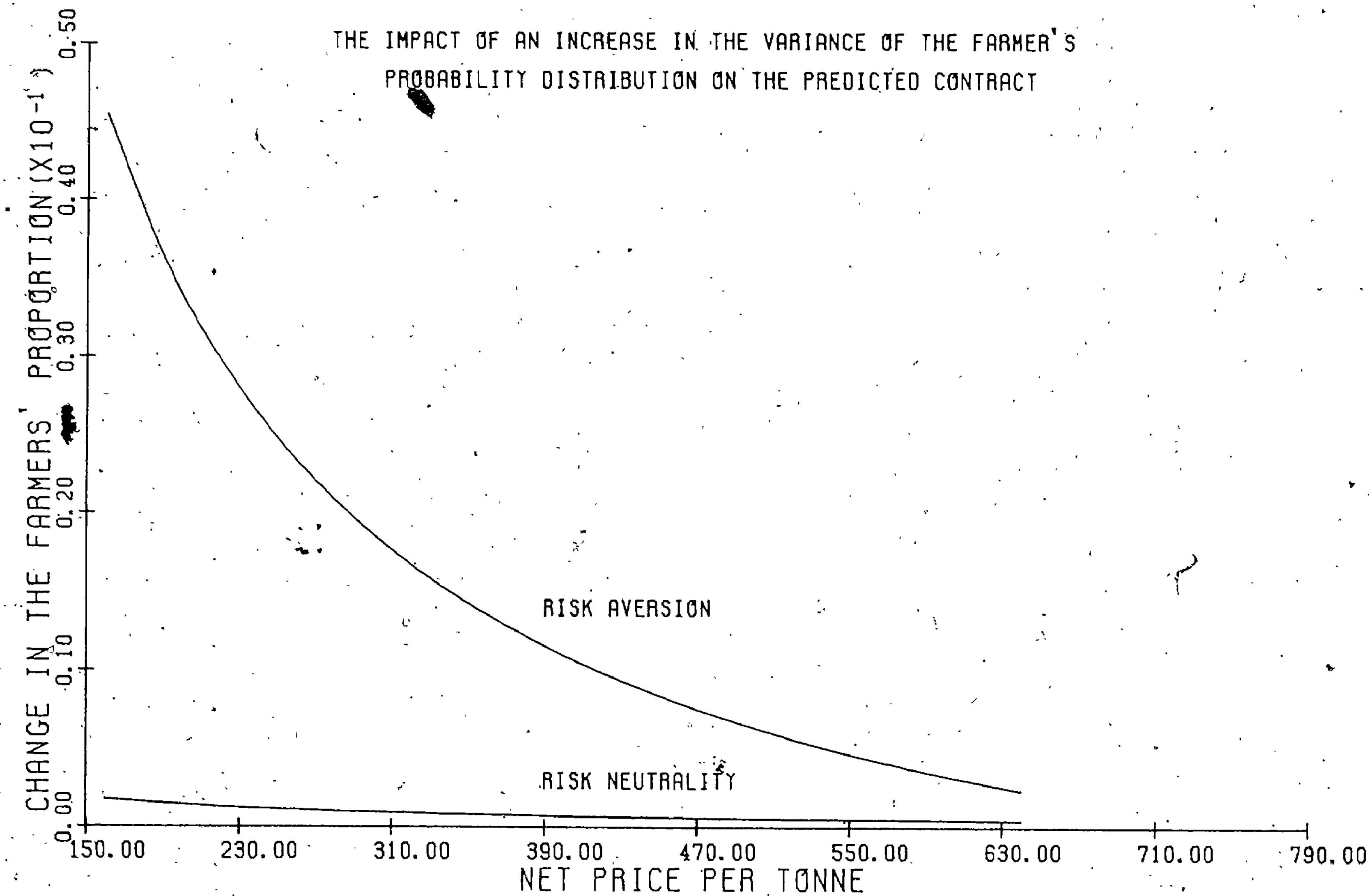


FIGURE V-D

THE IMPACT OF AN INCREASE IN THE MEAN OF THE TWO INDIVIDUALS PROBABILITY DISTRIBUTIONS ON THE PREDICTED CONTRACT

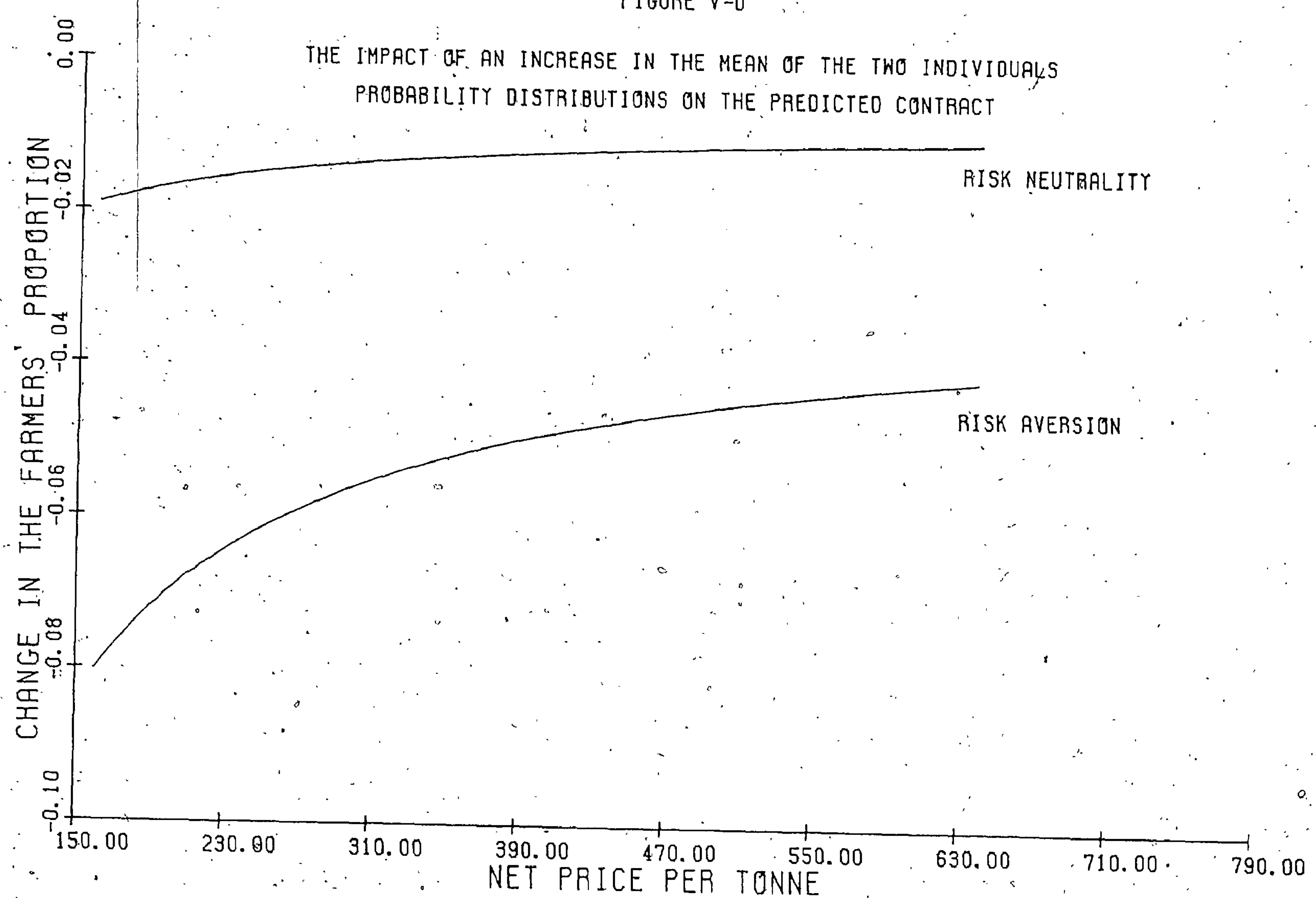


FIGURE V-E

THE IMPACT OF AN INCREASE IN THE MEAN OF THE REFINER'S PROBABILITY DISTRIBUTION ON THE PREDICTED CONTRACT

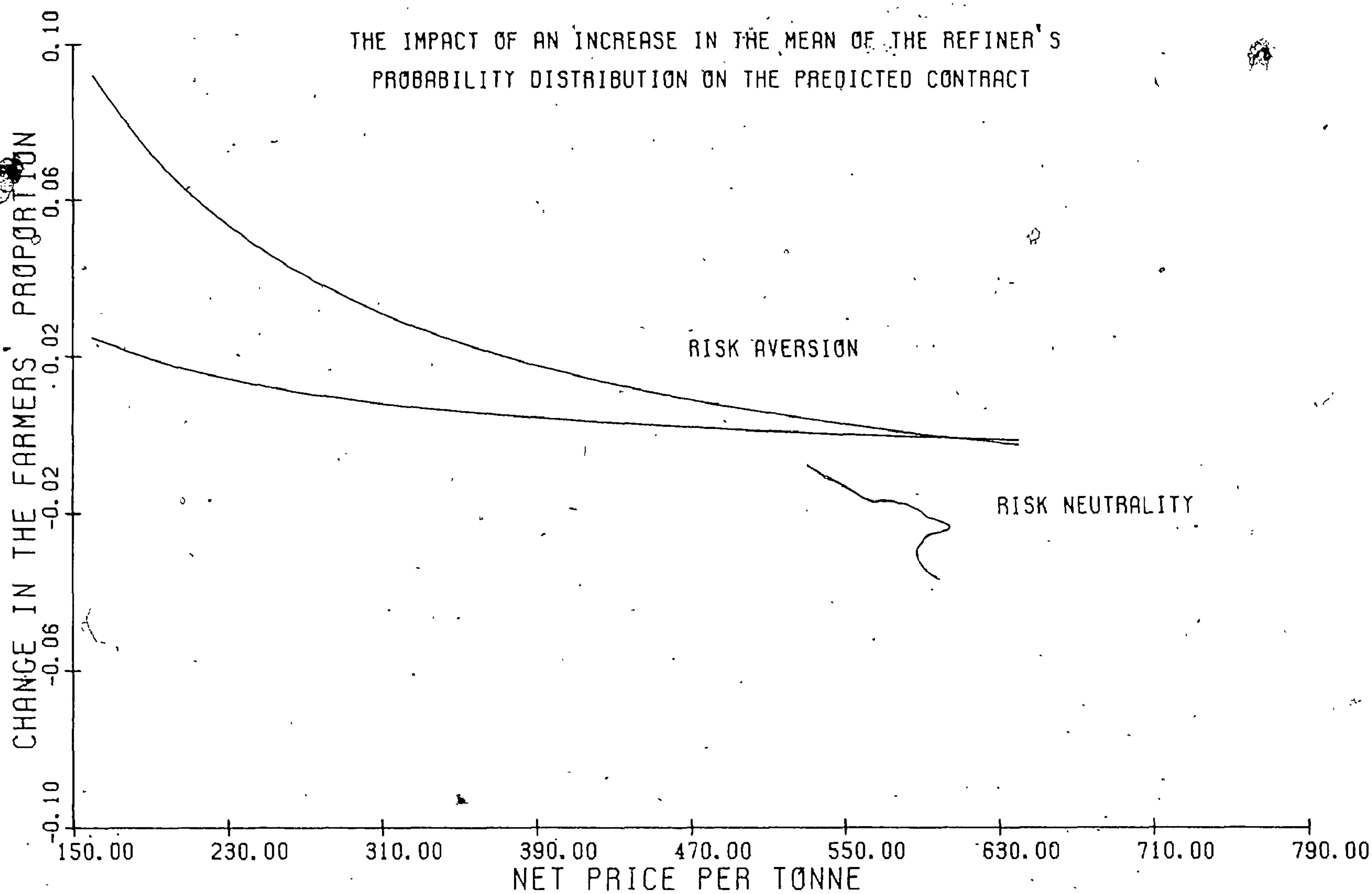


FIGURE V-F

THE IMPACT OF AN INCREASE IN THE MEAN OF THE FARMER'S PROBABILITY DISTRIBUTION ON THE PREDICTED CONTRACT

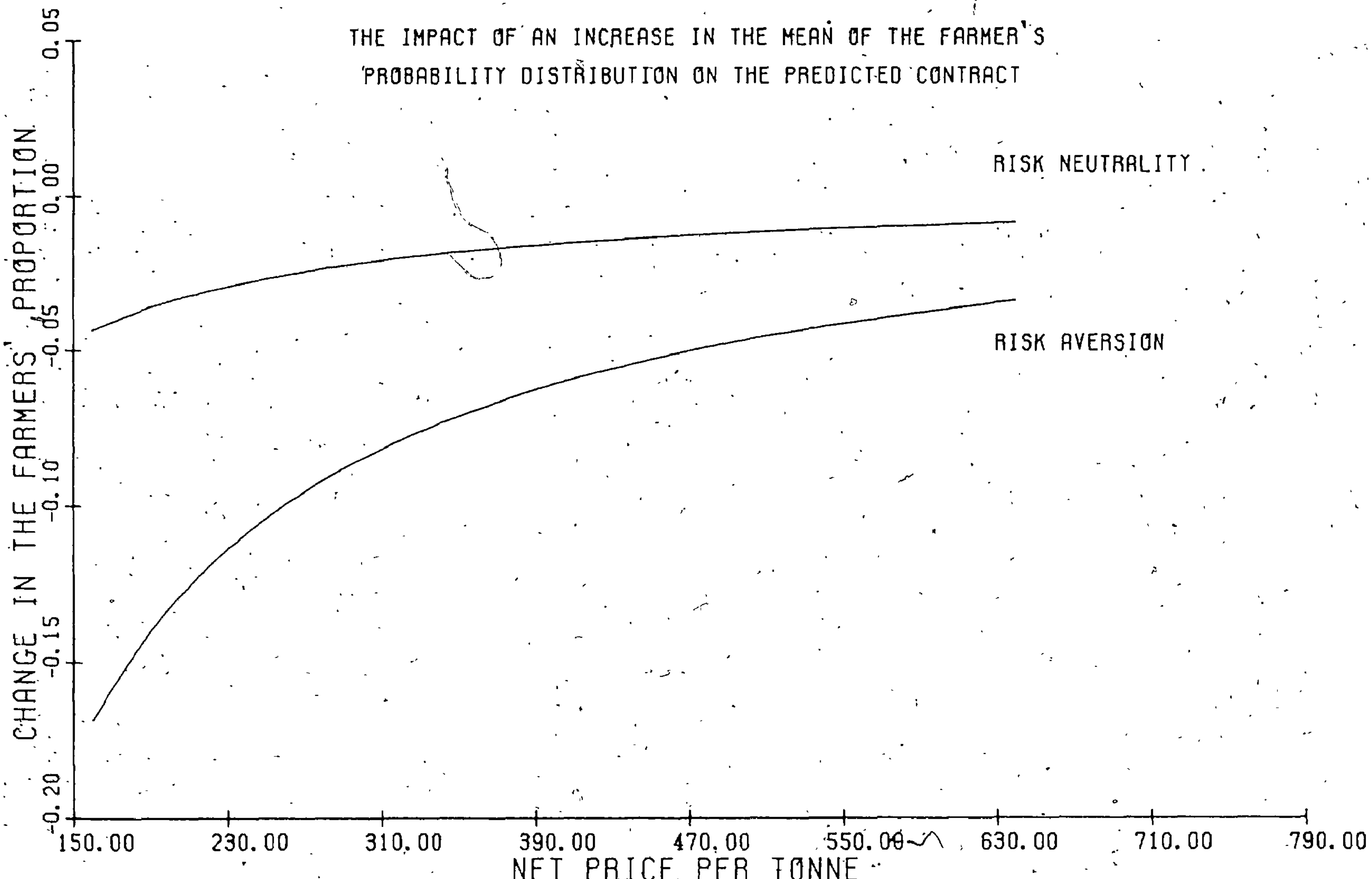


FIGURE V-G

THE IMPACT OF AN INCREASE IN THE FARMER'S DEGREE OF ABSOLUTE RISK AVERSION ON THE PREDICTED CONTRACT

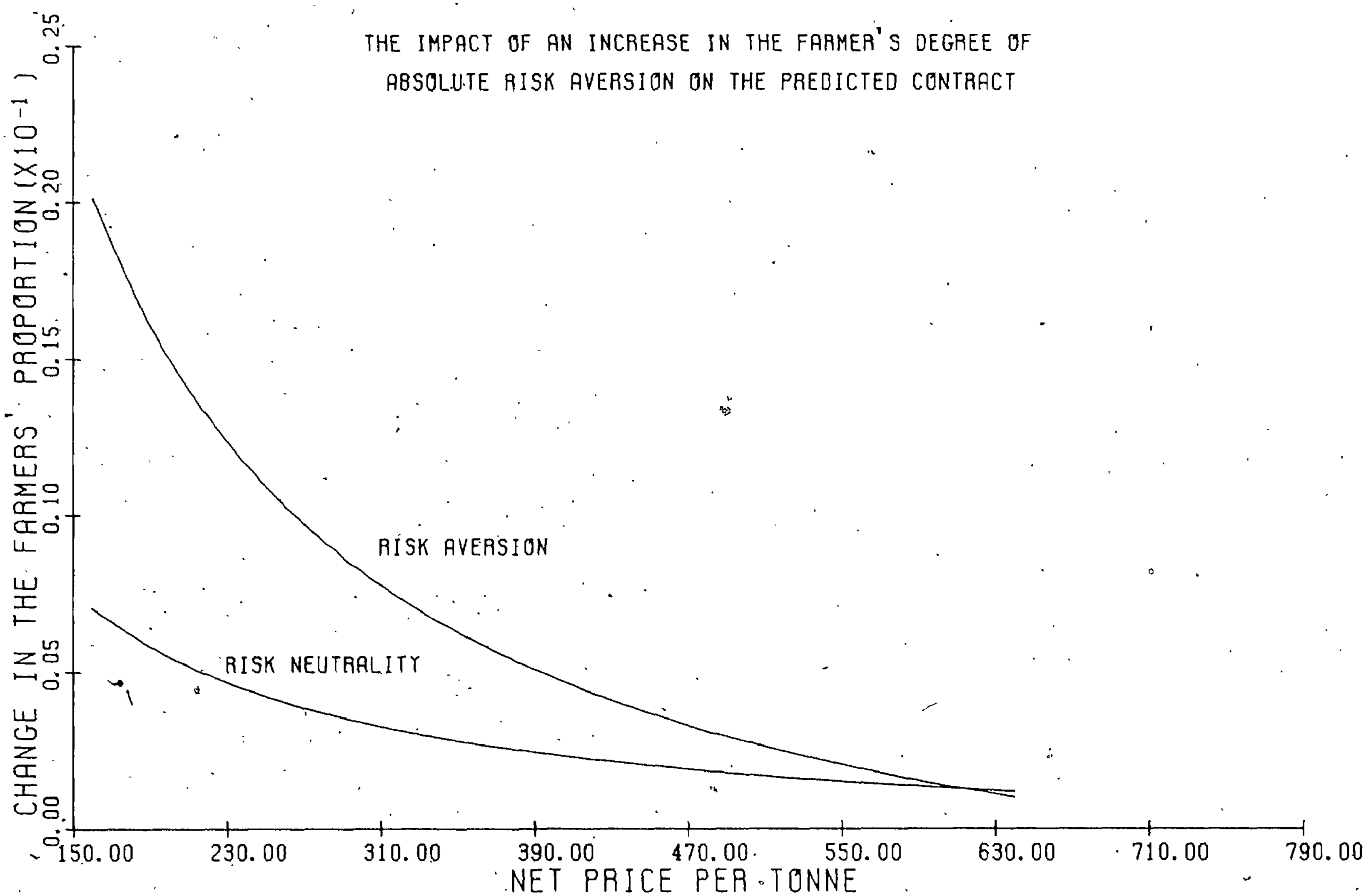
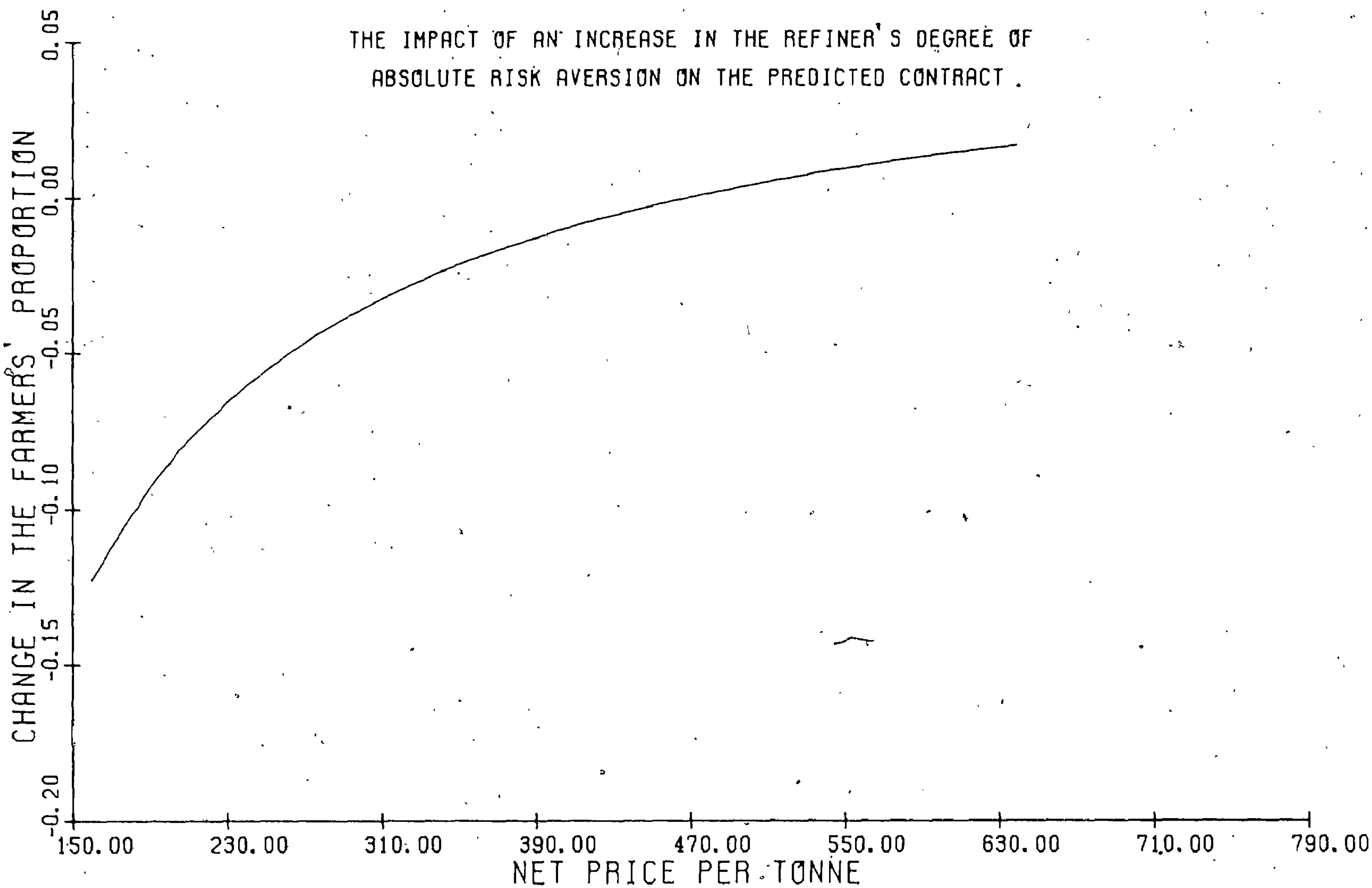


FIGURE V-H

THE IMPACT OF AN INCREASE IN THE REFINER'S DEGREE OF ABSOLUTE RISK AVERSION ON THE PREDICTED CONTRACT.



ondary effects have a moderating influence. For both a risk averse and a risk neutral refiner, the above changes will force the farmer's welfare below the minimally acceptable level, requiring a reduction in B.

Figure V-C shows how these changes interact in influencing the predicted relationship between the net price and the farmers' proportion. We find that even in the case of a risk neutral refiner, the reduction in B is sufficiently strong to force an increase in the proportion of the net price which the farmers are to receive, and therefore in their receipts per tonne. This result should have been expected because if the farmers are to be willing to operate in what they view as an increasingly risky environment, they will demand that their receipts per tonne increase.

Row 3 and Figure V-B report the effects of a mean preserving spread in the refiner's subjective probability distribution. A risk neutral refiner will not react to this change: Table V-B-2 confirms our expectations. For a risk averse refiner, on the other hand, his expected marginal utility of profit has decreased. It follows that the refiner could moderate the reduction in his welfare by altering the terms of the contract: both θ and A are reduced. In turn, the incentive effects would lead the farmers to respond to these changes by increasing fertilizer use. Also, the increase in B indicates that these changes are sufficiently powerful to force the farmer's expected utility above the constrained level; permitting an increase in the lump-sum transfer. From Figure V-B we find that while the increase in B will, to a certain extent, offset the decrease in θ, the overall effects on the farmers' share are crucially dependent on the ex post value for the net price.

Row 2 of Tables V-B-1 and V-B-2 along with Figure V-A report the effects of a simultaneous and identical mean preserving spread in both the refiner's and the farmer's subjective probability distributions. When the two adjustments occur simultaneously, we find that their associated impacts are almost perfectly counterbalancing in the cases of θ and F. It is only in the magnitudes of contracted acreage and the revenue transfer that we observe a significant overall change. When we depict the combined changes in Figure V-A we find that the changes in B and A are sufficiently large to force an increase in the proportion of the net price which the farmers are to receive.

In the analysis to this point, we have considered changes in the variances of the two subjective probability distributions. Row 7 of Tables V-B-1 and V-B-2 and Figure V-F report the effects of an increase in the mean of the farmer's distribution. The impact effect of this change would be an increase in fertilizer use. Since the refiner would observe the farmer's expected utility rising above the minimally acceptable level, he realizes that by altering the terms of the contract he could capture some of the profits generated by the additional use of fertilizer, while still being able to motivate farmers to enter into a contract. This would be accomplished by decreasing θ and increasing A. Given the direction of the incentive effects, these latter changes would have opposing effects on F. Whether they have a moderating or intensifying influence is not generally known, however in our case we find that fertilizer use is left increased. Once the various changes interact, Figure V-F leads us to conclude that the farmers' share will decline.

An increase in the mean of the refiner's probability distribution (row 6 and Figure V-E) will lead the refiner to increase both θ and A:

the farmers would respond by reducing fertilizer use. The changes in A and F interact so as to force an increase in the production of refined sugar. These movements, in conjunction with the alterations in θ and B, force an increase in the farmers' share.

As our final exercise relating to the random variable, we consider simultaneous increases in the means of the two probability distributions. We find that the two sets of adjustments act in tandem with respect to A, i.e., in both cases A increases. The changes in θ and F, on the other hand, differ in the two cases. Upon examining rows 5, 6, and 7 in Tables V-B-1 and V-B-2, we find - in the case of a risk averse refiner - that the increase in fertilizer use which would be induced by an increase in the farmer's mean is overwhelmed by the reduction which would follow from the increases in A and θ: the opposite result holds in the case of a risk neutral refiner. As we would expect, Figure V-D shows that the terms of the overall contract are quite responsive to any changes in expectations regarding the price at which the refined sugar will be sold.

As was mentioned previously, three sets of factors interact in determining the characteristics of the relationship that exists between the net price received for the refined sugar, and the farmers' share. To this point we have concentrated on the nature of the subjective probability distributions over the price of refined sugar for the refiner and farmers, respectively. It is clear, however, that the attitude toward risk of our individuals must be an important factor in any consideration of this issue. Rows 8 and 9 of the two tables, and Figures V-G and V-H report the results of first an increase in the farmer's degree of absolute risk aversion, and then the refiner's.

As in the previous cases, we describe the adjustment towards a new equilibrium position by distinguishing between the impact effects of a change, and the secondary effects associated with the refiner's understanding of the farmers' behavior pattern, i.e., those associated with the incentive effects. With an increase in the farmer's degree of absolute risk aversion, their immediate response would be to lessen the inherent risk through a reduction in fertilizer use. The refiner would also be aware of the farmers' increased aversion towards risk and would try to accommodate them by increasing θ and reducing A. However, due to his knowledge regarding the incentive effects, the refiner is aware that the farmers would react to these latter changes by reducing fertilizer use even more. In order to counter this, secondary changes are required. The refiner would moderate the increase in θ in order to motivate the farmers to increase fertilizer use, while reducing contracted acreage further to strengthen the effect on F. Figures V-G summarizes these changes, and demonstrates quite clearly that the farmers becoming more averse to risk will lead to an adjustment in the terms of the contract which leaves them receiving an increased proportion of the net price, i.e., they demand a higher payment if they become more concerned about the riskiness of the environment in which they are operating.

Row 9 of Table V-A-1 and Figure V-H report the effects of an increase in the refiner's degree of absolute risk aversion. The refiner would attempt to lessen the risk that he faces by reducing both θ and A, while increasing B. In turn, the farmers would respond to these changes by increasing fertilizer use. Figure V-H makes it quite clear, however, that whether the reduction in θ will overwhelm the increase in B, will depend on the price actually received for the refined sugar.

To this point in our analysis, the figures have allowed us to depict how the changes in θ, B, A, and F caused by some autonomous shock interact in altering the farmers' overall share of the net price. In addition to this, they also allow us to compare risk averse and risk neutral behavior by the refiner with respect to any differences in the functional relationships that arise between the two cases when a comparative static exercise is carried out. These differences can be of two types: either a variation in the farmers' share with the slopes being identical at any particular net price, or some divergence in the slope. Our results are consistent for both exercises: we find the impacts in the case of a risk averse refiner overwhelm those when the refiner is risk neutral. As a particular example, let us consider a mean preserving increase in the variance of the two probability distributions (Figure V-A). While in both cases, we observe reductions in θ, B, and the output of refined sugar, the overall effect of these changes is 'stronger' in the risk averse case. That is, the farmers' share both increases by more, while being more dependent on the actual net price. These results are intuitive because while a risk neutral refiner will be more passive in responding to any change which causes some change in the riskiness of the situation - he will only be concerned with the direct response of the risk averse farmer - a risk averse refiner will also be concerned with the risk that he, himself, faces and will therefore be more likely to adjust the terms of the contract and fertilizer use.

V.5. Sensitivity Analysis

In Chapter IV it was recognized that three factors determine the characteristics of the contractual relationship that exists between the refiner and growers of sugar beets. First of all, the nature of the subjective probability distributions over the price of refined sugar. Second, the attitudes towards risk of the farmers and refiner, respectively. And finally, the incentive effects. In Section V.4. we observed how the terms of the contract and fertilizer use are affected by marginal changes in the first two sets of factors. Of course, it was impossible to change the incentive effects since their magnitudes are determined endogenously. In obtaining the results summarized above, it was necessary to specify values for the parameters of the model. Since our choices for them are to a certain extent arbitrary, it is crucial that we show how sensitive the results summarized in Section V.4. are to our selection of parameter values.

Our approach in carrying through with this exercise is straightforward. Let us recall that the coefficients which characterize both the production (K_1 and m) and cost of refining relationships (C_1, C_2, and C_3), along with the refiner's degree of absolute risk aversion ($\overset{*}{u}$), are specified exogenously; as are the coefficients which characterize the subjective probability distribution (q=j and W=G), the farmer's degree of absolute risk aversion ($\overset{*}{v}$), and the minimally acceptable level of farmer welfare ($\bar{U}_T$) - the last four being determined by the computer algorithm. On the other hand, the values for land and fertilizer costs (a and r), and the return accruing to the farmer both as manager and from his labor ($\tilde{T}$) are estimated from available information. Of course, the values that we specify for the nine parameters whose values we choose are to a certain extent arbitrary. In Tables V-C-1, V-C-2, and V-C-3 we examine whether the results vis-a-vis θ, A, and F which are summarized in Section V.4. are sensitive to our choices. A row considers a particular comparative static exercise, while a column represents what happens if we alter one (or more) of the variables whose magnitudes we specify exogenously. Thus in Table V-C-3 and for a risk averse refiner, 0.97 is the elasticity of fertilizer use (F) that is associated with an increase in the mean of the farmer's subjective probability distribution as we move away from the original (benchmark) solution. The value 0.96 reports the same elasticity if we alter the refiner's degree of absolute risk aversion ($\overset{*}{u}$), recalibrate the model to the benchmark solution, then carry through with the same comparative static exercise. Columns 3 and 4 carry out a similar exercise, this time with respect to adjustments in land and fertilizer costs, respectively. For column 5 the required adjustment is somewhat more complicated in that the characteristics of the production relationship are altered while leaving production of refined sugar per acre unchanged, i.e., the new values for K_1 and m are chosen so that they offset one another perfectly. And finally, in column 6 the coefficients which characterize the cost of refining are altered so that the levels of both the average and marginal refining costs remain unchanged, while the functional relationship between the total production of refined sugar and average refining costs is altered. In columns 7 through 11, the same exercise is completed for a risk neutral refiner, and in column 12 the independent variables in the comparative static exercise are listed. Carrying through with an identical exercise for the revenue transfer component of contract (B) is impossible since we cannot compute a meaningful elasticity for B from the benchmark solution. Thus as an alternative indicator, in Table V-C-4 we report the impact on the revenue transfer per tonne of refined sugar - B/NQ.

Row 1 of the four tables report the effects of a simultaneous mean preserving spread in the two subjective probability distributions. We

TABLE V-C-1

SENSITIVITY ANALYSIS:

THE EFFECTS OF CHANGES IN THE KEY EXOGENOUS VARIABLES ON θ

Risk Averse Refiner						Risk Neutral Refiner					
Orig.	u^*	a	r	g(F)	C(NQ)	Orig.	a	r	g(F)	C(NQ)	Exog.
-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	q/W^2 & j/G^2
-0.21	-0.21	-0.20	-0.21	0.04	-0.22	0	0	0	0	0	q/W^2
0.18	0.18	0.17	0.19	0.13	0.17	-0.00	-0.00	-0.00	-0.00	-0.00	j/G^2
0.67	0.68	0.70	0.81	0.81	0.65	0.91	0.89	0.88	0.95	0.91	q/W & j/G
0.80	0.81	0.82	0.95	0.03	0.79	1.31	1.29	1.28	1.32	1.31	q/W
-0.27	-0.25	-0.22	-0.46	-0.00	-0.26	-0.41	-0.42	-0.43	-0.37	-0.41	j/G
0.18	0.18	0.15	0.15	0.12	0.15	0.03	0.03	0.03	0.05	0.03	v^*
-0.27	-0.27	-0.27	-0.28	-0.19	-0.27						u^*

TABLE V-C-2

SENSITIVITY ANALYSIS:

THE EFFECTS OF CHANGES IN THE KEY EXOGENOUS VARIABLES ON A

Risk Averse Refiner						Risk Neutral Refiner					
Orig.	$\overset{*}{u}$	a	r	g(F)	C(NQ)	Orig.	a	r	g(F)	C(NQ)	Exog.
-0.99	-0.99	-0.99	-0.99	-0.99	-1.02	-1.00	-1.00	-1.00	-1.00	-1.00	q/W^2 & j/G^2
-0.26	-0.26	-0.26	-0.26	0.12	-0.27	0	0	0	0	0	q/W^2
-0.74	-0.74	-0.75	-0.73	-0.79	-0.76	-1.00	-1.00	-1.00	-1.00	-1.00	j/G^2
2.99	3.00	3.05	3.49	3.25	2.94	2.58	2.56	2.52	2.71	2.58	q/W & j/G
1.22	1.22	1.22	1.61	0.05	1.20	2.01	2.04	2.04	2.07	2.00	q/W
1.85	1.85	1.88	2.15	0.08	1.82	0.60	0.57	0.54	0.68	0.60	j/G
-0.74	-0.74	-0.78	-0.77	-0.81	-0.78	-0.85	-0.85	-0.86	-0.77	-0.85	$\overset{*}{v}$
-0.28	-0.27	-0.28	-0.29	-0.23	-0.28						$\overset{*}{u}$

TABLE V-C-3

SENSITIVITY ANALYSIS:

THE EFFECTS OF CHANGES IN THE KEY EXOGENOUS VARIABLES ON F

Risk Averse Refiner						Risk Neutral Refiner					
Orig.	$\overset{*}{u}$	a	r	g(F)	C(NQ)	Orig.	a	r	g(F)	C(NQ)	Exog.
-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.01	0.01	0.01	0.01	0.01	q/W^2 & j/G^2
0.30	0.30	0.29	0.30	0.39	0.31	0	0	0	0	0	q/W^2
-0.28	-0.28	-0.28	-0.30	-0.22	-0.29	0.01	0.01	0.01	0.01	0.01	j/G^2
-0.37	-0.38	-0.40	-0.41	-0.59	-0.37	0.11	0.11	0.14	-0.02	0.11	q/W & j/G
-1.38	-1.37	-1.37	-1.78	-0.05	-1.34	-2.19	-2.22	-2.22	-2.25	-2.19	q/W
0.97	0.96	0.95	1.23	0.03	0.95	2.28	2.29	2.31	2.22	2.27	j/G
-0.29	-0.29	-0.26	-0.27	-0.21	-0.26	-0.12	-0.12	-0.11	-0.19	-0.12	$\overset{*}{v}$
0.33	0.32	0.32	0.34	0.27	0.33						$\overset{*}{u}$

TABLE V-C-4

SENSITIVITY ANALYSIS:

THE IMPACT OF CHANGES IN THE KEY EXOGENOUS VARIABLES ON B/NQ

Risk Averse Refiner						Risk Neutral Refiner					
Orig.	u^*	a	r	g(F)	C(NQ)	Orig.	a	r	g(F)	C(NQ)	Exog.
-2.73	-2.96	-3.05	-2.01	-0.19	-2.97	-0.28	-0.52	-0.39	-0.15	-0.30	q/W^2 & j/G^2
6.87	7.40	8.09	4.68	3.91	7.35	0	0	0	0	0	q/W^2
-9.18	-9.89	-10.6	-6.51	-1.24	-9.88	-0.28	-0.52	-0.39	-0.15	-0.30	j/G^2
8.29	7.26	5.35	19.00	1.85	7.88	1.92	3.74	4.35	0.05	1.68	q/W & j/G
-20.1	-17.6	-13.8	-41.3	-14.0	-19.2	-5.56	-11.3	-12.2	-0.18	-4.86	q/W
28.71	25.09	19.32	60.60	16.02	27.33	7.37	14.63	16.07	0.22	6.46	j/G
-4.08	-6.34	-31.2	-39.1	-9.69	-33.7	-1.25	-0.57	-1.16	-1.70	-1.21	v^*
29.78	29.18	29.37	30.73	23.39	29.74						u^*

observe that the results regarding the impacts on θ, A, and F are remarkably robust for both a risk neutral and a risk averse refiner. It is only with the revenue transfer per tonne that there seem to be noticeable differences. Let us recall, however, that the farmers' share of the net price is given by $((1 - \theta) - B/(NQP^{Net}))$. If the maximum divergence in B/NQ is in the neighborhood of 30.0, with a net price of \$500.00 per tonne the impact on the farmers' share will only be at the second decimal place. In other words, even relatively large differences in the revenue transfer will have minor impacts on the farmers' share.

When we consider a mean preserving spread of the refiner's probability distribution, with the farmer's remaining unchanged, the same conclusion follows - with one exception. For a risk averse refiner, the benchmark elasticity for θ has a value of -0.21, whereas when the production function's input elasticity is altered, θ's elasticity is now 0.04. The elasticites for contracted acreage and fertilizer use (0.12 and 0.39) also differ substantially from their benchmark values (-0.26 and 0.30) with that for A having the opposite sign. It follows that at least some of our results are dependent on those values we specify for certain parameters.

Regarding the effects of mean preserving spreads in the probability distributions (rows 4 through 6), the farmer's degree of absolute risk aversion (row 7), and the refiner's degree of absolute risk aversion (row 8), the results which we summarized in the previous section turn out to be quite robust. In fact, it is only in the case of a mean preserving spread of the refiner's probability distribution where the elasticity for two of contract terms changes sign.

V.6. Concluding Remarks

In this chapter we have reported the results of a computer simulation of the model that was developed in Chapter IV. Our goal was to use the computer as a tool in increasing our understanding of the relationship that exists between the refiner and the farmers. While this technique has not provided (and can not provide) any results in the theoretical sense, it has enabled us to show how the characteristics of the two subjective probability distributions, the farmer's and refiner's degrees of absolute risk aversion, and the incentive effects interacted in determining the nature of the predicted relationship between the net price and the farmers' proportion. As we would have predicted, views regarding the price (and variability in price) at which sugar can be expected to be sold must have been an important factor in the process which generated the actual contract. Also as expected were the results regarding marginal changes in the attitudes toward risk on both individual contractual terms and the overall payment scheme.

Endnotes

1. See Rothschild and Stiglitz (1970).

2. See Barr and Zehna (1971), p. 388.

3. The average sugar beet grower seeds 488 acres into various crops (including sugar beets). Using a wage rate of \$5.00 per hour, we estimate the cost of the owner's labor to be \$19520.00. Also we estimate the normal return accruing to the farmer as manager at \$12200.00. Thus, we specify a value for $\tilde{T}$ of \$31720.00 to be used in the simulation. As specified above, $\tilde{T}$ represents the normal return accruing to the farmer as manager and as laborer on his own farm. It follows that Y_T incorporates normal return along with the profit generated by the growing of sugar beets.

4. The refiner could directly adjust production of beets, and therefore refined sugar, either by altering contracted acreage or the number of contracts issued. In our analysis, we have treated the number of contracts to be issued as an exogenous variable. The rationale being that if the number of contracts is altered, this would typically be accomplished either by issuing an additional contract to a farmer who already holds one, or by withdrawing a contract from a farmer who holds more than one. Given this presumption regarding the manner in which the number of contracts would be changed, and that the number of acres issued per contract can be altered, it follows that making N a choice variable would be redundant since the individual farmer would view the two changes as being equivalent: in both cases, the number of acres he is permitted to seed into beets has changed.

5. See Mansur and Whalley (1984), p. 86.

6. The study is listed in the bibliography as follows: The Economics of Sugar Beet Production in Southern Alberta (1975,1976,1977).

7. See Mansur and Whalley (1984), p. 93.

8. Let us recall that while the degree of absolute risk aversion allows us to characterize an individual's attitude toward risk, it is not the only method available to us. For instance, the concept of a risk premium represents an alternative indicator. Formally, the risk premium (R) is defined as $E(U(W)) = U(E(W) - R)$. In our framework, it represents the expected income that the individual farmer is willing to give up in order to attain a risk-free situation. It follows that we could use the concept of a risk premium in specifying a particular value for the minimally acceptable level of welfare for the farmers, i.e., $\bar{U}_T = -\,\text{Exp}(-\,\bar{v}(E(\tilde{Y}_T) - R)$; where R is treated as a parameter whose value we would choose during the process of calibration, and $E(\tilde{Y}_T)$ represents the farmer's expected income if he produced an alternative crop. It is clear, however, that the information requirements of the alternative approach are greater than those of the first one.

9. According to the actual sugar beet contract, the farmers will receive between 58% and 63% of the value of the refined sugar produced from that year's crop: the share being determined by the price (net of refining costs) received for the sugar. For more than twenty years, however, the net price of refined sugar has been sufficiently high - not less than \$154.00 per tonne - so that the farmers' share has been constant at 63%. Since we are carrying out the the simulation experiment to aid in our understanding of the actual contractual relationship, in our benchmark solution the farmers' proportion of the net price must lie at a constant 63% level, i.e., $(1 - \theta) = 0.63$ and $B = 0$.

10. Since the benchmark solution value for B is zero, this prevents us from computing a meaningful elasticity for B when an exogenous variable changes. It is for this reason that only the sign of the new value for B is reported with the elasticities for the other endogenous variables in Tables V-B-1 and V-B-2.

11. In the case of a risk averse refiner and prior to changing any parameters, we assume:

$g(F) = 0.036F^{0.75}$,
$C(NAg(F)) = 0.00001(NAg(F))^2 + 15.0NAg(F) + 166876.$,
$N = 685$,
$a = 237.0$, and
$r = 1.35$.

In the case of a risk neutral refiner and prior to changing any parameters, we assume:

$g(F) = 0.047F^{0.70}$,
$C(NAg(F)) = 0.00001(NAg(F))^2 + 15.0NAg(F) + 166876.$,
$N = 685$,
$a = 237.0$, and
$r = 1.35$.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In the preceding chapters we were concerned with modelling, then analyzing, the relationship that exists between the refiner and growers of sugar beets. We recognized that their arrangement is quite unusual when compared to those found elsewhere in the agricultural sector. For instance, that which we observe in the sugar beet industry represents an intermediate case, between what we find in the grain and tomato industries. As with grain, the farmers are not supervised in the primary production of beets. As with tomatos, the processor and individual farmers sign a contract prior to the actual seeding of the beets in the early spring. The contract specifies both an acreage allotment, and a payment scheme. But here we must be careful because whereas the tomato farmer is guaranteed a fixed price for his product, the sugar beet grower receives no such guarantee. In fact, the contract specifies that the refiner and farmers will share in the net-revenue generated by the sale of refined sugar, their respective shares being dependent upon the average price at which the sugar is sold.

In this thesis we have adopted a particular contract structure which is consistent with the beet sugar industry in western Canada, and illustrated the impact of various risk parameters on contractual terms and input decisions: there was no attempt made to explain what characteristics in the sugar beet industry lead to a contract which doesn't involve monitoring of inputs. In considering this problem, we recognized that both the refiner and the farmers have variables they unilaterally control: the latter, the actual production process; the former, the nature of the payment scheme and contracted acreage. Having specified the problem in this manner, the next logical step was recognizing the relevance of the work done on principal-agent relationships. Applying this theory to the case at hand, the individual farmer will choose the amount of variable input to be applied per acre, under the assumption that the characteristics of the contract will remain invariant. When setting the terms of the contract, the refiner, on the other hand, will realize that any alteration in the contract will cause the farmers to change fertilizer use. Below we summarize the important results of the preceding chapters.

Chapter II The Institutional Framework of the Sugar Beet Industry

Fully 90% of the sugar consumed in Canada is obtained from imported raw cane. The remaining 10% is refined from sugar beets which are grown in southern Alberta, southern Manitoba, and near St. Hilaire in Quebec. In this chapter we reviewed some of the more interesting characteristics of the sugar refining industry in Canada.

We pointed out that most of the raw cane is purchased on the international 'free market' from countries which are subject to the British Preferential tariff. After the raw cane is delivered to the Canadian refiners and it's impurities are removed, the resulting refined sugar is sold in Canada under a basing point pricing scheme. Redpath is the acknowledged price leader in the industry, and through collusive behavior, the refining firms have been able to keep their profits quite high.

The beet sugar industry in western Canada is clearly influenced by the actions of the eastern Canadian refiners. For instance, the price at which refined cane sugar from Toronto could be sold in Edmonton will constrain B.C. Sugar in the price that they can charge for beet sugar. While B.C. Sugar acts as a monopolist in the sale of refined sugar in western Canada, the firm operates as a monopsonist in the 'purchase' of sugar beets. However, the beets are not 'purchased' in the traditional sense. Instead, the farmer's beets are delivered to the refinery and the sugar is extracted. Once this sugar is sold, then the refiner and the growers divide the proceeds - net of refining costs - on the basis of a contract that is signed in the early spring. The focus of this entire thesis has been an analysis of this contract.

Chapter III Survey of the Literature

This chapter is devoted to a survey of the relevant literature on share contracts. While there were precursors -see Jones(1964), Mill(1929), and Smith(1937)- the first 'modern' treatment of sharecontracting was that of Marshall(1966). Within the context of a deterministic model, he used his marginal analysis to demonstrate that sharecropping would lead to an underutilization of resources. But within his framework, one crucial variable was left unexplained - the shares of output to be received by the tenant and the landlord, respectively. Whereas Marshall treated it as being exogenous, and for this reason found that resources would be underutilized, Cheung(1969) recognized that the landlord must offer the tenant an income level under sharecropping which precisely equals that which could be earned elsewhere. Because of this, the 'share' must be treated as an endogenous variable. Once this extension was made, Cheung found that the misallocation problem disappeared. But this was due to a very important implicit assumption that Cheung had built into his model. Not only did the contract specify a payment scheme, a specification of tenant effort was also included. Of course, the landlord must then be able to monitor the effort of the tenant in order to guarantee the fulfillment of the contract. In general, however, it is not necessarily worth the cost to monitor input use and this appears to be the case, for example, in the sugar beet industry in western Canada. Thus, a reasonable extension of Cheung's model would be the inclusion of an additional factor of production, with the tenant having the choice over it's pattern of utilization.

Given the inherent riskiness of agricultural production, it was clear that tenancy agreements were best analyzed in an uncertainty framework. In Section 3 we surveyed the recent stochastic literature. Much of it was concerned with a stochastic version of Cheung's, or an extended Cheung-type model.

Chapter IV An Analysis of the Contractual Arrangement between the Processor and Producers of Sugar Beets

In this chapter we constructed a stochastic model of the the relationship that exists between the refiner and growers of sugar beets. The farmer assumed complete control over fertilizer usage, while the choice of contract was left to the refiner. The refiner recognized the adaptive nature of the farmer's decision, and took advantage of that knowledge when choosing the payment scheme. Below we summarize the main results of the chapter:

(i) If the farmers are risk averse and the refiner is risk neutral, and if the perceptions of the random variable's distribution are identical across individuals, then $0 < \theta < 1$.

(ii) If all individuals are risk averse, and

(a) the two subjective probability distributions are identical, then

(1) sharecropping occurs - $0 < \theta < 1$.

(2) $B < 0$ when both the refiner and the farmers have constant relative risk aversion functions, the farmers are 'more' averse to risk, and $F_\theta \gtreqless 0$.

(b) if either $E_R(P) > E_T(P)$ or $Var_R(P) < Var_T(P)$, then

(1) $B < 0$ if all individuals have constant relative risk aversion utility functions, $F_\theta \gtreqless 0$, and the farmers are 'more' averse to risk.

(2) $\theta = 0$ implies $E_T(P) > E_R(P)$.

(3) $\theta = 1$ implies $E_T(P) < E_R(P)$.

(4) $0 < \theta < 1$ when $Var_T(P) \neq Var_R(P)$.

Chapter V Simulation Experiment

We begin this chapter by specifying the format for the two individual's utility and probability density functions: the choices being crucial if the problem is to be made tractable. We assume that the random variable follows the gamma probability distribution, while a risk averse individual has a constant absolute risk aversion utility function: this combination simplifies the mathematics considerably.

In examining the results of the simulation, we found that marginal changes in attitudes toward risk and the variability in the price at which the refined sugar would be sold had significant impacts on the overall payment scheme. Also important were individual perceptions of the level at which the sugar would be sold.

When considering the question of suggestions for further research, we concentrate on possible extensions to the theoretical framework that was developed, then analyzed, in Chapter IV. Within the context of that model, risk was introduced through price uncertainty. Generally speaking, however, the amount of sugar obtained from a tonne of beets cannot be predicted with certainty in the early spring. Thus, a reasonable extension of the framework would be the consideration of simultaneous output, and price uncertainty.

And finally, a share contract is generally regarded as a mechanism whereby the risk associated with agricultural production is allocated among individuals. Thus, through risk spreading, activities would be engaged in, that may not occur if one person was forced to absorb all of the inherent production risk. But this statement reminds us of the risk-shifting aspects of insurance. Thus, an obvious extension of the model would be the addition of a competitive insurance market.

APPENDIX

In Chapter IV we related characteristics of the contract and fertilizer use, to the attitudes toward risk of the refiner and the farmers. Basing our analysis on the actual contract, we assumed the payment scheme was linear and that the cost of monitoring exceeded the benefits. While not being relevant to the basic purpose of the thesis, it is of theoretical interest to consider the characteristics of the payment scheme when it is not constrained to be linear, and when input use is monitored. Below we address this issue.

Let $Z = PAg(F) - C(NAg(F))/N$ = net-revenue obtained from the sale of sugar refined from one farmer's beets. Also, $X(Z)$ = the pareto optimal payment schedule. Then

$$E(U_T) = \int U_T(Z - X(Z) - rAF - aA)f_T(Z)dZ$$

= expected utility accruing to an individual farmer, and

$$E(U_R) = \int U_R(X(Z))f_R(Z)dZ ,$$

= expected utility accruing to the refiner; where

$f_R(Z)$ = the farmer's subjective probability density function for Z, and

$f_T(Z)$ = the refiner's subjective probability density function for Z.

The pareto optimal contract may be determined as the solution to the following maximization procedure.

$$\underset{(X(Z),K)}{\text{Max}}\ L = E(U_R(Y_R)) + K(E(U_T(Y_T)) - \bar{U}_T)$$

The first order conditions are a maximum are given by

$$U_R'(X(Z))f_R(Z) - KU_T'(Z - X(Z) - rAF - aA)f_T(Z) = 0 \qquad (A1)$$

for all Z, and[1]

$$E(U_T(Y_T)) - \bar{U}_T = 0 .$$

The question of primary importance to us is the nature of the pareto optimal payment scheme - whether it is linear, or not. Upon totally differentiating (A1), we obtain

$$U_R''f_R(Z)dX/dZ - KU_T''(1 - dX/dZ)f_T(Z) + U_R'f_R'(Z) - KU_T'f_T'(Z) = 0. \qquad (A2)$$

After using (A1) to solve for the Lagrange multiplier, then substituting the result into (A2), we find

$$\frac{dX}{dZ} = \frac{\frac{-U_T''}{U_T'} + \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right]}{\left[\frac{-U_R''}{U_R'} - \frac{U_T''}{U_T'}\right]} .$$

Let

R_P^R = the refiner's degree of risk tolerance, and

R_P^T = the farmer's degree of risk tolerance; then[2]

$$\frac{dX}{dZ} = \frac{R_P^R + \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] R_P^R R_P^T}{(R_P^R + R_P^R)} \qquad (A3)$$

The nature of dX/dZ is crucial. For instance, if dX/dZ is a constant then linearity of the pareto optimal payment schedule will be the result. On the other hand, if dX/dZ is, itself, some function of Z, then X(Z) will be either a concave or convex function.

From (A3),

$$\frac{dX}{dZ} = \frac{R_P^R + \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] R_P^R R_P^T}{(R_P^R + R_P^T)} \qquad \text{(A4)}$$

$$= \frac{R_P^R}{(R_P^R + R_P^T)} + U(Z),$$

where

$$U(Z) = \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] R_P^R R_P^T/(R_P^R + R_P^T) \ . \qquad \text{(A5)}$$

Thus

$$\frac{d^2X}{dZ^2} = \frac{((R_P^R + R_P^T)R_P^{R\prime}X' - R_P^R(R_P^{R\prime}X' + R_P^{T\prime}(1 - X')))}{(R_P^R + R_P^T)^2} + U'(Z)$$

$$= \frac{(R_P^T R_P^{R\prime}X' - R_P^R R_P^{T\prime}(1 - X'))}{(R_P^R + R_P^T)^2} + U'(Z) \ ,$$

then from (A4)

$$\frac{d^2X}{dZ^2} = \frac{R_P^T R_P^R(R_P^{R\prime} - R_P^{T\prime})}{(R_P^R + R_P^T)^3} + \frac{U(Z)(R_P^{R\prime}R_P^T + R_P^R R_P^{T\prime})}{(R_P^R + R_P^T)^2} + U'(Z)$$

where

$$U'(Z) = \frac{((R_P^R + R_P^T)(C(R_P^{R\prime}R_P^T + R_P^R R_P^{T\prime}) + R_P^R R_P^T C') - C R_P^R R_P^T(R_P^{R\prime} + R_P^{T\prime}))}{(R_P^R + R_P^T)^2},$$

and

$$C = \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right]. \qquad \text{(A6)}$$

Therefore

$$U'(Z) = \frac{C(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{(R_P^R + R_P^T)} + \frac{C' R_P^R R_P^T}{(R_P^R + R_P^T)} - \frac{C R_P^R R_P^T}{(R_P^R + R_P^T)} \left[\frac{R_P^{R\prime} + R_P^{T\prime}}{R_P^R + R_P^T}\right],$$

hence

$$U'(Z) = U(Z)\frac{(R_R^{T\prime} R_P^T + R_P^R R_P^{T\prime})}{R_P^R R_P^T} + U(Z)\frac{C'}{C} - U(Z)\left[\frac{R_P^{R\prime} + R_P^{T\prime}}{R_P^R + R_P^T}\right],$$

and

$$U'(Z) = U(Z)\left[\frac{(R_P^{R\prime} R_P^T + R_P^{T\prime} R_P^R)}{R_P^R R_P^T} - \frac{(R_P^{R\prime} + R_P^{T\prime})}{(R_P^R + R_P^T)} + \frac{C'}{C}\right]. \qquad \text{(A7)}$$

It follows that

$$\frac{d^2X}{dZ^2} = \frac{R_P^R R_P^T (R_P^{R\prime} - R_P^{T\prime})}{(R_P^R + R_P^T)^3} + U(Z)\frac{(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{(R_P^R + R_P^T)^2} + U'(Z). \qquad \text{(A8)}$$

After substituting (A7) into (A8), we obtain

$$\frac{d^2X}{dZ^2} = \frac{R_P^R R_P^T (R_P^{R\prime} - R_P^{T\prime})}{(R_P^R + R_P^T)^3} + U(Z)\frac{(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{(R_P^R + R_P^T)^2} + U(Z)\frac{C'}{C}$$

$$+ U(Z)\frac{(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{R_P^R R_P^T} - U(Z)\frac{(R_P^{R\prime} + R_P^{T\prime})}{(R_P^R + R_P^T)}$$

$$= \frac{R_P^R R_P^T (R_P^{R\prime} - R_P^{T\prime})}{(R_P^R + R_P^T)^3} + U(Z)\frac{C'}{C}$$

$$+ U(Z)\left[\frac{(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{(R_P^R + R_P^T)^2} + \frac{(R_P^{R\prime} R_P^T + R_P^R R_P^{T\prime})}{R_P^R R_P^T} - \frac{(R_P^{R\prime} + R_P^{T\prime})}{(R_P^R + R_P^T)}\right]$$

$$= \frac{R_P^R R_P^T (R_P^{R\prime} - R_P^{T\prime})}{(R_P^R + R_P^T)^3} + U(Z)\frac{C'}{C}$$

$$+ \frac{U(Z)}{R_p^R R_p^T (R_p^R + R_p^T)^2} \begin{bmatrix} R_p^R R_p^T (R_p^{R\prime} R_p^T + R_p^R R_p^{T\prime}) \\ - (R_p^{R\prime} + R_p^{T\prime})(R_p^R + R_p^T) R_p^R R_p^T \\ + (R_p^{R\prime} R_p^T + R_p^{T\prime} R_p^R)(R_p^R + R_p^T)^2 \end{bmatrix}$$

$$= \frac{R_p^R R_p^T (R_p^{R\prime} - R_p^T)}{(R_p^R + R_p^T)^3} + \frac{U(Z) C'}{C}$$

$$+ \frac{U(Z)}{R_p^R R_p^T (R_p^R + R_p^T)^2} \begin{bmatrix} R_p^T R_p^{T\prime} ((R_p^R)^2 + 2R_p^R R_p^T) \\ + R_p^{R\prime} R_p^T ((R_p^T)^2 + 2R_p^R R_p^T) \end{bmatrix}. \qquad (A9)$$

And finally, if we substitute (A5) and (A6) into (A9) we obtain the following expression.

$$\frac{d^2X}{dZ^2} = \frac{R_p^R R_p^T (R_p^{R\prime} - R_p^{T\prime})}{(R_p^R + R_p^T)^3}$$

$$+ \frac{\left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] \begin{bmatrix} R_p^{T\prime} R_p^R ((R_p^R)^2 + 2R_p^R R_p^T) \\ + R_p^T R_p^{R\prime} ((R_p^T)^2 + 2R_p^R R_p^T) \end{bmatrix}}{(R_p^R + R_p^R)^3}$$

$$+ \frac{R_p^R R_p^T}{(R_p^T + R_p^R)} \, d \left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] / dZ \, . \qquad (A10)$$

We begin our analysis by assuming that $f_R = f_T$ for all Z; then $dX/dZ = R_p^R/(R_p^T + R_p^R)$. It follows that:

(i) $dX/dZ = 1$ if the refiner is risk neutral and the farmers are risk averse, and

(ii) $0 < dX/dZ < 1$ if all individuals are risk averse.[3]

The first result demonstrates that the pareto optimal payment scheme will be linear, with the risk neutral refiner absorbing all of the inherent risk. On the other hand, (ii) implies that the contract will include a sharing of the net-revenue from the sales of refined sugar if all individuals are risk averse. At this point, however, we do not know whether the contract is linear, or not. From (A10),

$$\frac{d^2X}{dZ^2} = \frac{R_p^R R_p^T (R_p^{R\prime} - R_p^{T\prime})}{(R_p^R + R_p^T)^3} .$$

Thus, the contract will be linear if the behavior of both individuals is marked by constant absolute risk aversion (risk tolerance) - $R_p^{R\prime} = R_p^{T\prime} = 0$. We can strengthen this result by recognizing that the pareto optimal contract will remain linear so long as $R_p^R = R_p^T \neq 0$. On the other hand, the contract will be convex (concave) as $(R_p^{R\prime} - R_p^{T\prime}) \gtrless 0$.

RESULT A-1: If the refiner and farmers are risk averse and their subjective probability distributions are identical, then the pareto optimal payment scheme is convex, linear, or concave as $(R_p^{R\prime} - R_p^{T\prime}) \gtreqless 0$.[4]

Let us consider the case where $R_p^{T\prime} > R_p^{R\prime} > 0$; then with an increase in net-revenue, the aversion toward risk will decrease at a faster rate for the farmers than for the refiner. It follows that the farmers will accept more of the inherent risk as the level of net-revenue increases, i.e., the pareto optimal payment scheme will be concave. The argument will be reversed when $R_p^{R\prime} > R_p^{T\prime} > 0$, leading to a convex arrangement. And finally, when $R_p^{R\prime} = R_p^{T\prime}$ the forces precisely counterbalance one another, and a linear payment scheme will be the result.

Let us now extend the analysis by permitting f_R and f_T to differ. From (A4), if $R_p^{R\prime} = R_p^{T\prime} = 0$ - both individuals exhibit constant absolute risk aversion - then

$$\frac{d^2X}{dZ^2} = \frac{R_P^R R_P^T}{(R_P^R + R_P^T)} \, d\left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] / dZ \; . \tag{A11}$$

While it is not possible to make any general statements about the sign of d^2X/dZ^2, below we examine a specific probability density function which will provide this information.

EXAMPLE: The random variable is assumed to be distributed normally.

$$f_R(Z) = \frac{\mathrm{Exp}(-\,(Z - u_R)^2/2o_R^2)}{\sqrt{2\pi}\, o_R}$$

and

$$f_T(Z) = \frac{\mathrm{Exp}(-\,(Z - u_T)^2/2o_T^2)}{\sqrt{2\pi}\, o_T} \; ,$$

where

$$E_R(Z) = u_R \qquad E_T(Z) = u_T$$

$$\mathrm{Var}_R(Z) = o_R^2 \qquad \mathrm{Var}_T(Z) = o_T^2 \; .$$

Then,

$$f' = \frac{-\,(Z - u)f}{o^2} \; .$$

and

$$\left[\frac{f_R'}{f_R} - \frac{f_T'}{f_T}\right] = \frac{-\,(Z - u_R)}{o_R^2} + \frac{(Z - u_T)}{o_T^2} \; , \tag{A12}$$

hence

$$d\left[\frac{f'_R}{f_R} - \frac{f'_T}{f_T}\right] \Big/ dZ = \frac{(\sigma_R^2 - \sigma_T^2)}{\sigma_R^2 \, \sigma_T^2} \quad \text{(A13)}$$

According to Rothschild and Stiglitz (1970), it is a difference in variance which is the appropriate measure of the refiner and the farmers differing views of the riskiness of the situation. Using (A11) in conjunction with (A13), we find that the pareto optimal payment scheme will be convex/concave as $\sigma_R^2 \gtrless \sigma_T^2$. We interpret this result in the following manner: beginning with the case in which the variances of both the refiner's and farmer's subjective probability density functions are identical, the pareto optimal contract will be linear. That is, the refiner and farmers will receive a constant proportion of the value of refined sugar sales - independent of the state of nature. As the refiner's variance increases relative to that of the farmer, the refiner's share of sales revenue will increase with the level of 'output'. This result is to be expected because the increase in σ_R^2 will lead to an increase in the variance of the refiner's profit. Since he is risk averse, there must be a compensating increase in his expected profit. This is accomplished through an increase in the refiner's share.

RESULT A-2: If all individuals exhibit constant risk tolerance and treat net-revenue as being distributed according to a normal probability density function then the optimal payment schedule will be convex/concave as $Var_R(Z) \gtrless Var_T(Z)$.

It is natural for us to consider situations in which the means of the two random variables differ with variances remaining the same. From

(A10) and (A11), we find that $d^2X/dZ^2 = 0$ so long as $R_P^{R'} = R_P^{T'} = 0$. That is, if the degree of risk tolerance remains constant for all individuals, then the payment schedule will be linear. While differences in the means of the two distributions will typically influence the characteristics of the contract, its linearity will remain unaffected.

Let us now make a marginal extension of the analysis by considering the case where $R_P^{R'} = R_P^{T'} \neq 0$ and $Var_R(Z) = Var_T(Z)$, then

$$\frac{d^2X}{dZ^2} = \frac{R_P'(u_R - u_T)\ ((R_P^R)^2 + (R_P^T)^2 + R_P^R R_P^T)}{\sigma^2(R_P^R + R_P^T)^2} \ . \qquad \text{(A14)}$$

If $R_P' > 0$ and $u_R > u_T$, (43) implies that $d^2X/dZ^2 > 0$ and the optimal contract is convex. Beginning with a situation in which the means are identical, the contract will be linear. By itself, the assumption that $R_P' > 0$ is not sufficient to alter this conclusion: note how this is consistent with RESULT A-2. The previous paragraph leads to an identical conclusion when $R_P' = 0$, even though $u_R = u_T$. It is only when both $R_P' \neq 0$, and $u_R \neq u_T$ that the two sets of forces are sufficiently strong to prevent the payment schedule from being linear. We summarize the results below.

RESULT A-3: If

(i) the net-revenue from the sale of refined sugar is distributed normally,

(ii) the degree of risk tolerance is changing at the same rate for all individuals,

then the pareto optimal payment schedule is

a) convex if either $R_P' < 0$ and $E_R(P) < E_T(P)$, or $R_P' > 0$ and $E_R(P) > E_T(P)$,

b) concave if either $R_P' > 0$ and $E_R(P) < E_T(P)$, or
$R_P' < 0$ and $E_R(P) > E_T(P)$.

We complete the analysis by permitting the two individuals' degrees of risk tolerance to change at different rates. An analysis similar to that outlined above will yield the following results.

RESULT A-4: If

either $\begin{cases} \text{(i) } R_P^{R\prime} > R_P^{T\prime} > 0 , \\ \text{(ii) } E_R(P) \geqq E_T(P) , \end{cases}$

or $\begin{cases} \text{(iii) } 0 > R_P^{R\prime} > R_P^{T\prime} , \\ \text{(iv) } E_R(P) \leqq E_T(P) , \end{cases}$

then the pareto optimal payment schedule with be convex.

RESULT A-5: If

either $\begin{cases} \text{(i) } R_P^{T\prime} > R_P^{R\prime} > 0 . \\ \text{(ii) } E_R(P) \leqq E_T(P) , \end{cases}$

or $\begin{cases} \text{(iii) } 0 > R_P^{T\prime} > R_P^{R\prime} , \\ \text{(iv) } E_R(P) \geqq E_T(P) , \end{cases}$

then the pareto optimal payment schedule will be concave.

Let us recall from RESULT A-1 that a divergence between $R_P^{R\prime}$ and $R_P^{T\prime}$ will lead to a non-linear pareto optimal payment scheme. RESULTS A-4 and A-5 tell us that a difference in the two distribution's means will act to strengthen the tendency toward non-linearity.

Endnotes

1. Similar issues are raised in Leland (1978), Raiffa (1968), and Ross (1973, 1974).

2. The degree of risk tolerance is the inverse of the degree of absolute risk aversion.

3. Identical results are obtained in Leland (1978).

4. The same results are obtained by Leland (1978), and Ross (1973, 1974).

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