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**Pooling and Pricing Schemes for Marketing
Agricultural Products**

I. Finkelstain, Z. Bar-Shira, S. Buccola

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**POOLING AND PRICING SCHEMES FOR
MARKETING AGRICULTURAL PRODUCTS**

by

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ABSTRACT

In recent years there has been a growing concern over the performance of Israeli and U.S. agricultural marketing organizations. In Israel, poor performance of some marketing institutions has led to radical reforms. Examples are the two leading export industries – citrus and flowers. In the U.S., growth of local market power is eliminating competitive row product prices which served as the basis for farmer cooperative payment plans. This research studies, theoretically, several aspects of the above problem and develops empirical methods to assess their relative importance.

The theoretical part deals mostly with two related aspects of the operation of processing and marketing firms. The first is the technological structure of these firms. To this end, we formalize a detailed theory that describes the production process itself and the firm's decision. The model accounts for multiple products and product characteristics. The usefulness of the theory for measurement of productivity and pricing of raw material is demonstrated. The second aspect of the processing and marketing firm that we study is unique to the agricultural sector, where many such firms are cooperatives. In such cooperative an efficient and fair mechanism for purchasing raw materials from members is crucial to successful performances of the firm. We focus on: 1) pricing of raw materials. 2) comparison of employment of quota and price regimes by the cooperative to regulate the quantities, supplied by members. We take into consideration that the cooperative management is subject to pressure from member farmers. 3) Tier pricing for raw materials in order to ensure efficiency and zero profits at the cooperative level. This problem is examined in both closed and open cooperatives.

The empirical part focuses in: 1) the development of methodologies for estimating demand for differentiated products; 2) assessing farmers response to component pricing; 3) measurement of potential and actual exploitation of market power by an agricultural marketing firm. The usefulness of the developed methodologies are demonstrated by several application to agricultural sub-sectors, including: U.S. dairy industry, Oregon wine industry, Israeli Cotton industry and Israeli Citrus industry.

Objectives of the Original research proposal and deviations

Objectives

- (a) Create a model of efficient coordination between the marketing, production, and *R&D* sectors.
- (b) Conduct a theoretical analysis of pricing policies and of their impact on equity and stability.
- (c) Quantify demand information using hedonic price approach.
- (d) Quantify supply information by way of multiproduct technology models.
- (e) Examine the farmers' responses to price incentives employing a nonparametric approach.
- (f) Conduct an empirical analysis of industry-level response to quality-differentiated pricing.
- (g) Examine factors influencing the position of the quality frontier, i.e., the supply of *R&D*.
- (h) Combine the above in a comprehensive industry-level welfare analysis.

Deviations

- (a) We have a preliminary version of this model, however, we did not estimated or calibrated the model.
- (b) We did not study the equity consequences of pricing policies, since we found that this issue was extensively studied. However, we did study the political consequences of different regulation policies within cooperatives.
- (c) We did not combine the different components of the study into a single welfare analysis in the industry-level. We find that this is a very complicated task, which requires further research.

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OVERVIEW

A significant proportion of Israeli and U.S. agricultural output is sold through marketing cooperatives or through such government-nominated agencies as marketing boards or marketing orders. Rather than maximize returns to owners of the marketing firms' stock, these agencies explicitly consider the interests of farm suppliers. Including farmer interests in marketing and pricing decisions may benefit farmers, but also raises serious conceptual and operational difficulties.

Farm suppliers differ from one another in preferences, objectives, and farm characteristics, and in the quality of raw farm product they supply to the marketing agency. Differences in farmers' preferences make it difficult for the marketing agency to adopt a stable, unified marketing plan. Differences in raw product characteristics complicate the task of pricing products at both final product and raw product stages.

Israel and the United States

Israel's producer-oriented marketing tradition has for the most part operated through marketing boards, whereas in the U.S. it has operated through marketing orders and privately organized marketing cooperatives. Most agricultural exports from Israel, for example, have until lately been sold by government-monopoly export company or marketing boards, which have officially acted in farmers' interests. Further, in several subsectors, such as the dairy industry, farm product is marketed through farmer-owned cooperatives. In the United States, approximately 25% of the value of farm product is handled and sold by farmer-owned cooperatives, including 80% of the milk, 43% of the cotton, 36% of the grain and oil seed, and 18% of fruits and vegetables. These cooperatives are wholly owned by their farmer members, although they usually lack the local monopoly power which marketing boards have by government fiat.

In recent years, the Israeli export sector has moved gradually away from domination by government marketing boards and toward greater reliance on private firms. Citrus marketing, once monopolized by a marketing board, has been transferred to private hands. Flowers now are exported both by a government company and by

private firms. Given the producer-oriented tradition of Israel's agricultural marketing system, many of the new marketing firms are likely to be controlled or heavily influenced by their farm suppliers, acting equivalently as cooperatives. Others probably will organize as investor-owned rather than supplier-owned firms. In order to compete with nearby cooperatives, many investor-owned marketing firms in the United States treat their farm suppliers essentially as owners, paying dividends to suppliers on the basis of the value of their raw product delivered to the firm.

Return Allocation Systems

In competitive markets, investor-owned processing/marketing firms have no difficulty determining compensation terms for farm suppliers of the raw product. Farmers simply are paid the market price for their raw product at time of shipment. Cooperative marketing agencies, on the other hand (with or without a government monopoly license), face a more difficult problem. The agency's net returns should be allocated among its farm suppliers, but the number of such allocation procedures is essentially infinite. Consider two extreme forms of allocation: (i) Complete pooling. The entire net returns in a given accounting period (week, month, year) are first pooled, then allocated to individual suppliers in proportion to the agency's valuation of each supplier's raw farm product. All product need not be marketed under a common brand name or quality label. However, the farm origin of raw product is lost once the product is delivered to the agency. (ii) Individual accounts. The farm origin of each unit of raw product is preserved. Each supplier is paid the revenue from sale of his own product on the final market, less the agency's processing/handling cost allocatable to this supplier and less an agreed share of the fixed or overhead cost (e.g. flower exchange markets in the Netherlands).

Many cooperative marketing agencies fall between these two extremes by conducting a family of pools. A separate pool may be conducted for any subset of product characteristics the agency chooses. For example, a separate pool may be operated for each identified raw product grade or for each geographic area of raw product origin. As the number of pools increases, the cooperative moves along the continuum from full pooling to the use of individual accounts. To the extent that some pooling is maintained and raw products are heterogeneous, the agency must value one supplier's raw product relative to all others, this is not a straightforward task if raw

product markets do not exist or are imperfectly competitive.

Advantages and Disadvantages of Pooling

Pooling has evolved in cooperatives and marketing boards for a number of reasons: (a) Pooling permits greater scale and scope economies than possible under less pooled environments. Because products whose returns will be pooled need not be kept separate on the assembly line, such functions as packaging, storage, and transportation can be conducted more flexibly and on a larger scale. In addition, cost and revenue accounting necessary for individual accounts or for numerous small pools is eliminated. (b) The product commingling that pooling permits may give the agency the volume or product breadth needed to exercise power in its customer or input markets. Such power may be used to increase returns to farm suppliers as a group.

Pooling allows the agency to conduct a flexible marketing strategy without unfairly penalizing individual suppliers. For example, the agency may use loss leaders, a grade or style of product priced on especially favorable terms in order to expand the agency's market for the remaining grades or styles. Producers of the discounted products would be penalized unless returns from all the products are pooled.

(d) Pooling reduces many suppliers' income risk below what it would be under individual income accounting. A necessary condition for such a reduction is that revenues and handling costs of the individual farm goods be less than perfectly positively correlated across farms, and this condition is usually satisfied to some degree. Risk reduction tends to increase with the heterogeneity of products included in the pool and with the length of the accounting period over which pooled revenues and costs are computed.

Unfortunately, pooling has a single serious disadvantage over nonpooled income allocation schemes: some pool suppliers tend to be subsidized by others. A subsidy arises when the pooling agency values a supplier's raw good disproportionately to the net value of that raw good in the final product market (Sosnick 1963; Buccola 1991; Buccola and Stokstad 1993). Suppliers taxed under such situations have an incentive to lobby for an improved allocation, to reduce the volume of product they supply to the agency's pool, or to leave the agency altogether. Subsidized suppliers, on the other

hand, have the opposite incentive, and in particular will seek to market through the agency a greater volume of product than the agency wants or than will maximize the agency's total return. The result is economic inefficiency, inequity, and institutional instability.

Economic inefficiencies created by such subsidies are similar to those in moral hazard environments. If one of two grades brings the marketing agency a higher net revenue than the other and if suppliers are paid the same pooled net return per quantity unit delivered to the agency regardless of quality, suppliers will seek to overproduce the lower- quality good in the sense that the marginal revenue to the supplier exceeds the marginal net revenue to the agency. A supplier seeks to equate marginal farm production cost to the marginal payment the agency offers him; this equality may not in fact be achievable and a corner solution may occur at the maximum or minimum (quota) volume the agency imposes. In the extreme, some producers may adversely select themselves out of the agency and sell instead through another firm (e.g. the Israeli flower industry). Average quality of the agency's product diminishes along with total net returns.

Inequities created by inter-supplier subsidies are best understood in the context of reasonable entitlement schemes. Most pool contributors probably feel entitled to the portion of pool net income which their own raw product contribution has generated. Subsidies ensure that such entitlements will not be realized and hence violate most suppliers' sense of distributive equity. This undermines the agency's stability and likely accounts for the failure of many marketing cooperatives and boards. Evidence suggests inter-member subsidies in marketing cooperatives can be very high (Buccola and Stokstad).

Toward Improved Pools

Allocative inefficiencies in marketing pools can be corrected. That is, a compromise model can be developed which retains the advantages of both pools and individual accounts. The solution requires that the marketing agency maintain information about market price differential between final products with differing characteristics, then utilize this information to determine the corresponding raw products' pool net return shares. Such a procedure would affect more than short-run

income allocations among farmers. In the longer run, farmers would respond to the changed price signals by altering supply quantities of the quality characteristics under their control. Altered characteristics supplies in turn would affect farm input demands and the agricultural research programs appropriate to the industry.

A system of continually updated differential prices for agricultural product characteristics would therefore serve a cooperative marketing agency in several ways: (i) it can be used to establish a premium/penalty system to ensure that market signals are passed on to farmers; and (ii) it would provide policy makers and investors with information useful for planning future *R&D* in agricultural production and processing. In addition, it would (iii) create a basis for market evaluation of new product varieties with desirable characteristics, and (iv) provide the information necessary for designing rational sorting and grading schemes themselves (*e.g.* Zusman 1967).

In this study, we laid out the basis, in the form of theoretical analysis and empirical methodologies, for pursuing some these goals with respect to several agricultural subsectors in Israel and the United States.

CHAPTER 1: RAW MATERIAL PRICING AND THEORY OF MANUFACTURING ENTERPRISES

INTRODUCTION

Since the early 1970s, technology and cost analysts have pursued increasingly flexible function specifications. Flexibility reduces the risk of maintaining restrictions that are unfulfilled in the data. But flexibility also has a drawback. An industry's technology profile probably depends in systematic ways on the types of goods or services which that industry provides. If so, using for a manufacturing industry the same restrictions employed to examine, say, financial services firms would compromise both statistical efficiency and economic insight.

In the present paper, I discuss some implications of the technological features one would expect to find in manufacturing operations, where raw or intermediate materials are processed in largely assembly-line fashion. I show that the seemingly mild technology conditions which typify manufacturing enterprises imply a form of almost-nonjoint technology in which the individual production relations exhibit quasi-fixed proportions. The latter restrictions in turn provide significant structure to the firm's cost minimization and profit maximization problems.

A principal theme of this article is that substitutability between materials and such value-adding inputs as capital and labor increases with, and is dependent upon, the degree of aggregation over product lines. In a disaggregated model, identifying a material's unit value and thus demand quantity requires distinguishing between the material's scale effect and composition effect on net returns. Failure to account for disaggregated production structure can have serious implications. For example, standard procedures for measuring aggregate productivity growth rates in manufacturing are shown to be potentially seriously biased.

1. Technology

Suppose there are I distinguishable products, $i = 1, \dots, I$, with quantity vector $\mathbf{q} \in \mathbb{R}^I$ and price vector $\mathbf{p} \in \mathbb{R}^I$. J distinguishable materials, $j = 1, \dots, J$, are to be combined in producing these I outputs, with quantity vector $\mathbf{m} \in \mathbb{R}^J$ and price vector $\mathbf{p}_m \in \mathbb{R}^J$. Let $\mathbf{m}_i = (m_{i1}, \dots, m_{iJ})$ be the $J \times 1$ vector of materials allocated to the i^{th} product, so that $\sum_i \mathbf{m}_i = (\sum_i m_{i1}, \dots, \sum_i m_{iJ}) = \mathbf{m}$. Then $\mathbf{s}_i = (m_{i1}/\sum_j m_{ij}, \dots, m_{iJ}/\sum_j m_{ij}) = (s_{i1}, \dots, s_{iJ})$ is the associated $J \times 1$ vector of material proportions in the i^{th} product. The situation here is similar to a network, although materials are not formally modelled as outputs (Fare and Grosskopf [1996]).

Three mild restrictions will be imposed on the technology.

Assumption 1: The quantity of the i^{th} product does not exceed the sum of the J material quantities used in its production:

$$(1) \quad q_i \leq \sum_j m_{ij} \quad (i = 1, \dots, I).$$

One might account for material waste by multiplying each m_{ij} in (1) by the proportion of the purchased quantity of that material which survives in the final product. Often, waste products are better considered as a subset of the firm's multiple outputs.

Assumption 2: A one-one mapping exists between the vector $\mathbf{c}_i$ of the i^{th} product's characteristics and a vector $(\mathbf{s}_i, \theta_i)$, in which the $\mathbf{s}_i$ are the material proportions and θ_i indicates the set of industrial treatments applied to these materials. It follows immediately that the material proportions in the i^{th} product are fixed:

$$(2) \quad s_{ij} = m_{ij}/\sum_j m_{ij} = s_{ij}^0 \quad (j = 1, \dots, J).$$

Vector (s_i, θ_i) accounts for all of the i^{th} product's utility, just as c_i does in the hedonic literature (Rosen [1975], Jones [1984]).¹ Thus also, the i^{th} product's sale price generally depends on material proportions s_i , on process θ_i , and on quantity q_i sold; that is, $p_i = p_i(s_i, \theta_i, q_i)$. If the firm is a price-taker, $p_i = p_i(s_i, \theta_i)$.

Assumption 3: Output q_i of the i^{th} product is bounded from above by a finite, differentiable, quasi-concave, and monotonically increasing function v_i of the value-adding (nonmaterial) inputs, independently of material quantities m_{ij} , $j = 1, \dots, J$.

To clarify Assumption 3, let $\mathbf{x}_i = (x_{i1}, \dots, x_{iK})$ be a $K \times 1$ vector, $k = 1, \dots, K$, of value-adding inputs allocable to the i^{th} product and $\mathbf{p}_x = (p_x^1, \dots, p_x^K)$ be its corresponding price vector. $\mathbf{z} = (z_1, \dots, z_N)$ will be an $N \times 1$ vector, $n = 1, \dots, N$, of value-adding inputs which are unallocable among products and $\mathbf{p}_z = (p_z^1, \dots, p_z^N)$ its corresponding price vector. The conventional value-adding inputs are capital and labor. Very generally, we can think of the technology as described by a finite transformation function

$T(\mathbf{q}, \mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{x}_1, \dots, \mathbf{x}_I, \mathbf{z}) = 0$. Assumption 3 says T must satisfy

$$(3) \quad \begin{aligned} q_i &\leq v_i(\mathbf{x}_i, \mathbf{z}) \\ \sum_i \mathbf{x}_i &= \mathbf{x} \end{aligned} \quad (i = 1, \dots, I)$$

Assumptions 1 - 3 together imply that T must satisfy

$$(4) \quad \begin{aligned} q_i &= \text{Min} [m_{i1}/s_{i1}, \dots, m_{iJ}/s_{iJ}, v_i(\mathbf{x}_i, \mathbf{z})] \\ \sum_i \mathbf{m}_i &= \mathbf{m} \\ \sum_i \mathbf{x}_i &= \mathbf{x} \end{aligned} \quad (i = 1, \dots, I)$$

in which the allocatively efficient firm equates $m_{i1}/s_{i1} = \dots = m_{iJ}/s_{iJ} = \sum_j m_{ij} = v_i = q_i$.

Kohli [1985, p. 384] and Livernois and Ryan [1989, p. 484] define as *almost nonjoint in input quantities and prices* any structure which may be written as $q_i = q_i(y_i, z)$, $\forall i$, $\sum_i y_i \leq y$, where y is the vector of total allocable input quantities. The i^{th} sub-technology in such a formulation can be specified as a function of inputs y_i proper to that sub-technology as well as of inputs z common to all sub-technologies. Observing in our notation that $y \equiv (m, x)$, model (4) clearly is a form of almost nonjoint structures in which each sub-production-function exhibits quasi-fixed proportions. In each sub-technology of (4), that is, the quantity of value added (which is a flexible function of the value-adding inputs) is held in fixed proportion to each of the material inputs, which in turn are held in fixed proportion to output. Yet ratios of raw material to final product are constant only for the i^{th} product design. Thus, unlike in the single-product case, substitutability among material proportions in (4) is limited only by the variety of products, which in turn depends on the degree to which raw materials can be unbundled from one another and on the sub-technologies available for recombining materials.²

2. Value-Added Cost Minimization

The hypothesis that (4) accurately describes a given manufacturing technology can be tested empirically. Kohli [1985, pp. 386 - 387] shows that a technology is almost nonjoint if and only if the joint allocable cost function $C_a(q, p_x, p_m, z)$ is the sum of the allocable costs of the I individual product lines. Thus also, the allocable cost function's output quantity hessian matrix is diagonal: $\partial^2 C_a(q, p_x, p_m, z) / \partial q_i \partial q_{i'} = 0$, $\forall i, i'$. In addition, Diewert [1971, pp. 503 - 504] has demonstrated that the i^{th} sub-technology has quasi-fixed proportions if the generalized Leontief approximation to its allocable cost function satisfies

$\partial^2 C_{al,i}(q, p_x, p_m, z)/\partial p_x^k \partial p_m^j = 0, \forall k, j$, that is if interaction terms between prices of value-adding inputs and prices of materials are zero. These conditions can be tested in conjunction with an appropriately flexible functional form.

Fixed ratios of outputs to material inputs simplify cost analysis to some extent. Because material quantities and costs are known once output quantities q_i are fixed, the firm need only minimize with respect to the cost of value-adding inputs. However, this simplification is partly illusory. The value-added cost minimization problem with technology (4) is 3

$$(5) \quad C(m_1, \dots, m_I, p_x, p_z) =$$

$$\text{Min}_{x_i, z \geq 0} \{ (\sum_i p_x x_i + p_z z) \mid [q_i^\circ = (\sum_j m_{ij})^\circ \leq v_i(x_i, z)], i = 1, \dots, I; \sum_i x_i = x \}.$$

From Assumption 3, marginal products of the value-adding inputs depend on material proportions $s_{ij}, \forall i, j$. Thus, minimized cost depends not just on output volumes, but on the quantity of each raw material in each final product.

Assuming interior solution $x_i, z > 0, \forall i$, the Lagrangian of (5) is $L_1 = \sum_i p_x x_i + p_z z - \sum_i \lambda_i [v_i(x_i, z) - q_i^\circ]$, with first-order conditions

$$\begin{aligned}
(6) \quad (a) \quad p_x^k &= \lambda_i \partial v_i(\mathbf{x}_i, \mathbf{z}) / \partial x_{ki} & (k = 1, \dots, K) \\
(b) \quad p_x^k &= \lambda_i \partial v_i(\mathbf{x}_i, \mathbf{z}) / \partial x_{ki} & (k = 1, \dots, K) \\
(c) \quad p_z^n &= \sum_i \lambda_i \partial v_i(\mathbf{x}_i, \mathbf{z}) / \partial z_n & (n = 1, \dots, N) \\
(d) \quad q_i &\leq v_i(\mathbf{x}_i, \mathbf{z}) & (i = 1, \dots, I) \\
(e) \quad \sum_i \lambda_i [v_i(\mathbf{x}_i, \mathbf{z}) - q_i] &= 0. \\
(f) \quad \lambda_i &\geq 0 & (i = 1, \dots, I)
\end{aligned}$$

and complementary slackness conditions $(q_i = v_i) \Rightarrow (\lambda_i \geq 0)$; $(q_i < v_i) \Rightarrow (\lambda_i = 0)$, $i = 1, \dots, I$.

If the gradient vectors $\mathbf{D}v_i(\cdot)$ corresponding to the binding constraints $(\lambda_i \geq 0)$ are linearly independent of one another, a solution to (6) and thus to the minimization problem exists (Arrow, Hurwicz, and Uzawa [1961]).

Besides Lagrange nonnegativities (6f), there are $KI + N + I + 1$ conditions to be solved in (6). The i^{th} equation block in (6a) - (6b) equates the i^{th} technology's K -dimensioned gradient vector of allocable inputs to the vector of prices of the allocable inputs expressed per unit of the i^{th} multiplier. Thus, the ratio of the $(i, k)^{\text{th}}$ to $(i, k^*)^{\text{th}}$ marginal product is equated to the corresponding input price ratio $p_x^k/p_x^{k^*}$, and (6a) - (6b) are the IK price-dependent conditional demands for allocable factors $\mathbf{x}$. By the same token, block (6c) are the N conditional demands for unallocable factors $\mathbf{z}$. As Kohli has pointed out, an unallocable input behaves like a public good. No sub-technology can exclude its use, so efficiency requires equating the price of the unallocable input to the sum of the marginal cost savings which this input provides to all final products.⁴

Because a factor's allocation is assumed not to affect its price, (6) equates a given allocable input's marginal product across every final product. Thus also, the ratio of any two allocable inputs' marginal products is equated across every final product pair. These

conditions are determined simultaneously: each equation in (6a) - (6c) generally is a function of both $\mathbf{x}_i$ and $\mathbf{z}$. The effect on the i^{th} product quantity of an input allocable to that product is influenced by the levels of the unallocable inputs, which in turn are affected by inputs allocable to the i^{th} product.

It is useful to derive reasonable conditions under which this particular form of simultaneity would be eliminated, that is such that each allocable input's cost contribution to one product would be independent of the quantities of that input allocated to other products. As demonstrated in Appendix A, the following technology will produce the desired independence:

Result 1. Allocable inputs are optimally allocated among products independently of unallocable inputs if and only if a function of the allocable inputs and a function of the unallocable inputs each is a separate minimum production requirement for each product:

$$(7) \quad q_i = \text{Min} [m_{i1}/s_{i1}, \dots, m_{iJ}/s_{iJ}, g_i(\mathbf{x}_i), t_i(\mathbf{z})], \quad (i = 1, \dots, I)$$

where g_i and t_i are assumed monotonically increasing and concave in arguments.

In that case, and as also shown in Appendix A, value-added cost has the additively separable form

$$(5') \quad C(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_x, \mathbf{p}_z) = \sum_i C_{\text{al},i}(\mathbf{m}_i, \mathbf{p}_x) + C_{\text{un}}(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_z)$$

where $C_{\text{al},i}$ is the allocable value-added cost of the i^{th} product and C_{un} is unallocable value-added cost.

Notably, only one of the I restrictions $q_i \leq t_i(\mathbf{z})$ in (7) need be tight in any cost-minimizing program. Suppose that the i^{th} constraint $q_i \leq t_i(\mathbf{z})$ in Set U of equation (A.3) of Appendix A is a strict inequality. The i^{th} product then has zero marginal cost of unallocable

inputs, since by complementary slackness the i^{th} Lagrange multiplier γ_i is forced to zero. Hence, output price p_i need exceed only per-unit allocable cost $C_{al,i}(\mathbf{m}_i, \mathbf{p}_x)/q_i$ to induce positive production of the i^{th} good. We therefore have

Result 2. In separable technology (7), conditional demand prices $(p_i^c)^d$ of the unallocable inputs are unaffected by product quantities held below their critical points $t_i(\mathbf{z})$. In nonseparable technology (4), on the other hand, the point at which raising a product's output begins to augment the conditional demand for the unallocable inputs is determined simultaneously with the levels of all products' allocable inputs.

Zones in which products have zero marginal unallocable input cost help explain the belief that multiple products enable a firm to make optimal use of common resources. Once overhead costs are committed to one product, they are available free to the others up to each product's critical point. Below such points, overhead is fixed in the sense that optimal levels of the unallocable inputs won't change as the production plan changes. In general, however, overhead inputs are variable rather than fixed, with marginal costs imputable to given products. Technologies (4) and (7) both call into question the frequent accounting practice of allocating overhead cost to each product in proportion to its revenue or allocable cost.

3. Profit Maximization

Once the value-added cost of producing given quantities of given product designs is a minimum, profit is maximized by selecting the optimal set of product designs and optimal quantity of each design. A product design is determined by the proportions in which the materials are combined and by the technique used to process them. The parameters of the profit-maximum problem are the price vectors $\mathbf{p}$, $\mathbf{p}_x$, $\mathbf{p}_z$, $\mathbf{p}_m$; that is, the profit function is $\pi = \pi(\mathbf{p}, \mathbf{p}_x, \mathbf{p}_z, \mathbf{p}_m)$.

3.1. Optimization with Discrete Product Designs

The discrete approach to this selection problem is to identify arbitrarily an initial set of designs, then solve for the optimal quantity of each design. Some optimized quantities may be zero; the remainder will constitute the firm's optimal product configuration.

Assuming generally nonseparable technology (4), the problem is

$$(8) \quad \max_{\mathbf{q} \geq 0} \quad \pi = \sum_i p_i q_i - C(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_x, \mathbf{p}_z) - \sum_i \sum_j p_m^j q_i s_{ij}$$

$$s_{ij} = m_{ij}/q_i = s_{ij}^0 \quad (\forall i, j).$$

where C is value-added cost and the expression to the right of it is material cost, namely $\sum_i \sum_j p_m^j m_{ij}$. Optimal positive quantities of the I products are found by equating to zero the derivatives of (8) with respect to outputs:

$$(9) \quad p_i - \partial C(\cdot)/\partial q_i = \sum_j p_m^j s_{ij} \quad (i = 1, \dots, I).$$

In (9), the i^{th} product's marginal net revenue is equated to the weighted average price of the materials used in the i^{th} product's manufacture. Equations (9) give the firm's supply quantities as implicit functions of output and input prices.

Approach (8) - (9) has two drawbacks. First, a design that actually belongs in the optimal configuration may have been excluded from the originally proposed set. Thus, we will be confident we have found the profit-maximizing configuration only to the extent that the number of originally proposed designs is large. Second, firms often wish to know the contribution to profit of adding one more unit of a given raw material to a given product, assuming the quantities of the remaining materials are fixed. This *ceteris paribus* addition of a unit of material alters the product design itself because the addition induces marginal changes in the material proportions. Maintaining arbitrary product designs would not permit such alterations to occur. For these reasons, it is useful to represent the profit equation in a way permitting product designs to change marginally.

3.2. Optimization With Continuous Product Designs

We begin with a fixed number of product design slots. The optimal design in each slot and quantity of product in that slot are to be determined. This largely is the approach taken by Lancaster [1975], who represents a product by its characteristics vector rather than, as in the present analysis, its material proportions s_i and industrial treatment θ_i .⁵ Let $\alpha = (\alpha_1, \dots, \alpha_I)$ be the $A \times I$ matrix of parameters of value-added functions $v_1, \dots, v_I$, respectively. If $A \times 1$ vector α_i is a complete listing of the i^{th} sub-technology's parameters, we may write $v_i(\mathbf{x}_i, \mathbf{z}) = v(\mathbf{x}_i, \mathbf{z}; \alpha_i)$, where $v(\cdot)$ is a functional form common to every sub-technology.

As the i^{th} product design changes at the margin, the i^{th} sub-technology generally changes as well. For example, altering the ratio of fat to protein in cheese production changes not only the type of cheese but the technology available for manufacturing it. A product design can be altered by changing the percentage share of any of its raw materials. A marginal change in the j^{th} share, s_{ij} , generally will affect the i^{th} technology differently than does a marginal change in the j'^{th} share because each change generally has a different

implication for the remaining share levels.⁶ By assumption, the technological impact of a marginal change in s_{ij} is fully represented by the gradient vector of its effects on α_i , that is by the gradient vector $\partial \alpha_i^1 / \partial s_{ij}, \dots, \partial \alpha_i^J / \partial s_{ij}$. Thus, the J such gradient vectors are a full accounting of the technological effects of material share changes in the i^{th} product slot.

By way of hedonic price function $p_i(s_i, q_i, \theta_i)$, a change in the design of the i^{th} product also alters its output price p_i . And, just as with technology changes, the j^{th} material's proportionate share in the i^{th} product can affect p_i differently than does the j'^{th} material's proportionate share. If the firm is a price-taker, $p_i(s_i, q_i, \theta_i) = p_i\{s_i(\mathbf{m}_i), \theta_i[s_i(\mathbf{m}_i)]\} = p_i(\mathbf{m}_i)$. Taking these technology and price effects together, the profit maximum problem is

$$(10) \quad \max_{(\mathbf{m}_1, \dots, \mathbf{m}_I)} \pi = \sum_i p_i(\mathbf{m}_i) q_i - C(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_x, \mathbf{p}_z; \alpha) - \sum_i \sum_j p_m^j m_{ij}$$

$= R - \sum_i \sum_j p_m^j m_{ij}$, where $R = \sum_i p_i q_i - C$ is return over material expenditures. Problem (10) selects the quantity of each material in each product slot that maximizes total profit.

Consider the impact of changing the quantity of the j^{th} material in the i^{th} product slot. Holding $m_{ij'}$ constant, $j' \neq j$, and differentiating (10) with respect to m_{ij} gives

$$\begin{aligned}
(11) \quad \partial \pi / \partial m_{ij} = & p_i + q_i [(\partial p_i / \partial s_{i1})(\partial s_{i1} / \partial m_{ij}) + \dots + (\partial p_i / \partial s_{iL})(\partial s_{iL} / \partial m_{ij})] \\
& - [\partial C / \partial q_i + (\partial C / \partial s_{i1})(\partial s_{i1} / \partial m_{ij}) + \dots + (\partial C / \partial s_{iL})(\partial s_{iL} / \partial m_{ij})] \\
& - p_m^j \quad (\forall i, j).
\end{aligned}$$

A *ceteris paribus* increase in m_{ij} increases the proportion of material j in product i by amount $\partial s_{ij} / \partial m_{ij}$, and reduces the proportions of the other materials in product i by $\partial s_{ij'} / \partial m_{ij}$, $j' \neq j$. Each such proportion change is associated with a generally different change in product price and, through the technology parameters, in minimized cost. From the proportion identity $s_{ij} = m_{ij} / q_i = m_{ij} / \sum_j m_{ij}$, we have, for $j' = j$, $\partial s_{ij} / \partial m_{ij} = (q_i - m_{ij}) / q_i^2$ and, for $j' \neq j$, $\partial s_{ij'} / \partial m_{ij} = -m_{ij} / q_i^2$. Substituting these relations into (11), rearranging terms, and applying the Kuhn-Tucker conditions for a profit maximum: 7

$$\begin{aligned}
(12) \quad \partial R / \partial m_{ij} = & p_i - \partial C / \partial q_i \\
& + [\partial(p_i q_i - C) / \partial s_{i1}] [-m_{i1} / q_i^2] + \dots + [\partial(p_i q_i - C) / \partial s_{ij}] [(q_i - m_{ij}) / q_i^2] \\
& + \dots + [\partial(p_i q_i - C) / \partial s_{iL}] [-m_{iL} / q_i^2] \leq p_m^j \quad (\forall i, j).
\end{aligned}$$

The j^{th} material's marginal contribution to the i^{th} product's revenue net of minimized value-added cost cannot exceed the j^{th} material's price. I will refer to this marginal contribution -- the top three lines of (12) -- as the *j^{th} material's i^{th} marginal net revenue product*. It is an optimized marginal value in the sense that, while $m_{ij'}$, $j' \neq j$, are held constant, value-adding inputs $\mathbf{x}_i$, $\mathbf{z}$ adjust optimally to the change in m_{ij} .

3.3. Scale and Composition Effects

Increasing material quantity m_{ij} does two things: it increases the i^{th} product's quantity and simultaneously changes its composition. Marginal net revenue product in (12) accordingly can be divided into two effects. The *scale effect* (first line) is the i^{th} marginal net revenue, namely the change in net value caused by the increment in product quantity, holding material proportions constant. The *composition effect* (second and third lines) is the net value change resulting from the collective changes in material proportions, holding product quantity constant. In certain situations, such as when a furniture manufacturer alters the shape of a particular table style, changes in material proportions involve no real changes in sub-technology $v(\mathbf{x}_i, \mathbf{z}; \alpha_i)$. Terms $\partial C/\partial s_{ij}$ in (11) then go to zero and the composition effect consists solely of the influences of material proportions on output price. If output prices are unaffected also, composition effects vanish and the j^{th} material's i^{th} marginal net revenue product reduces to the i^{th} product's marginal net revenue $p_i - \partial C/\partial q_i$. In that event, continuous model (10) - (12) is equivalent to discrete model (8) - (9).

Corner solutions to the profit-maximizing program, where $m_{ij} = 0$ for some i and j , occur frequently and represent cases in which a product excludes certain raw materials. For example, if $m_{ij} = 0, \forall j \neq j^*$, the i^{th} product consists of material j^* only. If $m_{ij} = 0, \forall j$, the firm declines to fill the i^{th} product slot. The firm has no incentive to fill multiple slots if all value-adding inputs are allocable, since technology (4) would then be input-nonjoint. That is, the firm deploys multiple products only if scope economies are present in value-added cost function (5). As is clear from (6) and from our discussion of Result 1, scope economies are present only if products share unallocable inputs. Thus,

Result 3. A manufacturing firm optimally produces multiple products only to the extent that the products share unallocable value-adding inputs.

In a competitive market, it is reasonable to assume that input price p_m^j is the same across all products in which j is employed. Consider a situation in which two products, i and i' , each employ positive amounts of two materials j and j' (in other words, $m_{ij} > 0$ for i, i', j , and j'), so that (12) is a strict equality. The left-hand-side of (12) then must have the same value for i as it does for i' ; that is, j 's contribution to the value of the i^{th} product equals j 's contribution to the value of the i'^{th} product. Now suppose in addition that j 's composition effect in product i [second two lines of (12)] equals j 's composition effect in product i' . It follows that product i 's scale effect must equal product i' 's scale effect. But if the scale effects in the two products equal one another, j' 's composition effect in product i must equal j' 's composition effect in product i' also. This result is immediately generalizable to any number of materials or products:

Result 4. If one material has the same composition effect in two different products, the composition effect of every other material used in positive quantity must be invariant across the two products as well.

Of course, each material's composition effect is generally different from that of every other material.

3.4. Demands and Supplies

The i^{th} scale effect, $p_i - \partial C / \partial q_i$, in (12) is simultaneously determined with all other scale effects $p_{i'} - \partial C / \partial q_{i'}$, $i' \neq i$, since optimal output quantities are linked to one another by way of the unallocable inputs.⁸ By Assumption 1, each of the IJ first-order conditions (12) therefore is a function of all IJ material quantities m_{ij} :

$$(13) \quad p_m^j = p^{ij}(m_{11}, \dots, m_{1J}, \dots, m_{I1}, \dots, m_{IJ}, \mathbf{p}, \mathbf{p}_x, \mathbf{p}_z; \alpha), \quad (\forall i, j).$$

If material prices on the left-hand side are given, (13) may be solved for m_{ij}^d , $\forall i, j$, the firm's demands for each of the J materials in each of the I products, each expressed as a function of the prices of outputs, value-adding inputs, and material inputs. Summing over the I products gives the simultaneously determined total demands $m_j^d = \sum_i m_{ij}^d$ of the material inputs:

$$(14) \quad m_j^d = m_j(p_m, p, p_x, p_z; \alpha), \quad (j = 1, \dots, J).$$

Summing instead over the J materials gives the simultaneously determined total supplies $q_i^s = \sum_j m_{ij}^d$ of the final products:

$$(15) \quad q_i^s = q_i(p_m, p, p_x, p_z; \alpha) \quad (i = 1, \dots, I).$$

One can also view (13) as the set of J material demand prices $(p_m^j)^d$, that is, the maximum prices the firm would pay for materials given purchase quantities m_{ij} . Applications of this sort are useful for manufacturers who deal in imperfectly competitive materials markets, and who therefore may have discretion in setting prices to material suppliers. In competitive markets, on the other hand, a manufacturer must pay the material producer's supply price $(p_m^j)^s$, namely the marginal cost of material production. Aggregating over manufacturers' demands and equating supply and demand prices gives the IJ equilibrium quantities $(m_{ij})^*$ and J equilibrium prices $(p_m^j)^*$. These equilibria are conditioned by the prices (p_x, p_z) of value-adding inputs, by material producers' and manufacturers' technology parameters, and by any restrictions on producer inputs. In applications in which material supply functions are perfectly elastic, the general econometric problem is to estimate unconditional demands (14) as a system of J equations. Where material supplies are imperfectly elastic, statistical consistency requires that (14) be estimated in conjunction with the associated J material supply equations.

4. Illustration: Productivity Growth Rate Estimation

An important goal of the theory of the firm is to establish a basis for measuring aggregate productivity growth. In the standard production model $q = f(\mathbf{x}, \mathbf{z}, t)$, where f is differentiable and t a time variable, the primal rate of multifactor productivity growth is simply $\partial \ln f / \partial t$. (For one of many examples, see Jorgenson, Gollop, and Fraumeni [1987]). Quasi-fixed-proportions model (4), which I argue typifies manufacturing technologies, does not permit us to derive a primal productivity growth rate in such an unambiguous way. In a given product line, the rate of productivity growth in value added may differ from that in materials. Thus, it is more natural to work with the dual rate of productivity growth, namely the proportional change in the total cost of materials and value-added as input prices and output are held fixed.

Consider for simplicity the case in which each distinct product is fabricated from a single, distinct material. Let ψ_i be the rate at which the i^{th} material is transformed into the i^{th} final product, so that ψ_i is one minus the material cull rate. The first line of (4) may then be rewritten to permit the productivity growth rate in the value-added function to be separate from that in the material transformation parameter:

$$(16) \quad q_i = \text{Min} [m_i \psi_i(t), v_i(\mathbf{x}_i, \mathbf{z}, t)] \quad (i = 1, \dots, I).$$

Cost is minimized when the quantity of uncultured materials, $m_i \psi_i$, equals the quantity of value-added v_i . However, if the primal rate of productivity growth in material transformation differs from that in the value-added function ($\partial \ln \psi_i / \partial t \neq \partial \ln v_i / \partial t$), equality $m_i \psi_i = v_i$ cannot be maintained without continuous adjustment in at least some of the inputs $m_i, \mathbf{x}_i, \mathbf{z}$. Thus, condition $m_i \psi_i = v_i$ places restrictions on the input changes which occur in the background when one computes the i^{th} product's dual productivity growth rate $-\partial \ln C_i / \partial t$.

As shown in Appendix B, this dual measure is, in the case of quasi-fixed-proportions technology (16),

$$(17) \quad -\partial \ln C_T / \partial t = (p_m m / C_T) (\partial \ln \psi / \partial t) + (\partial C / \partial v) (v / C_T) (\partial \ln v / \partial t),$$

where i subscripts are dropped for notational simplicity, $C(v, \mathbf{p}_x, \mathbf{p}_z)$ is value-added cost, and $C_T = p_m m + C$ is total cost of materials and value-added. If value-added function $v(\mathbf{x}, \mathbf{z})$ has constant returns to scale, $\partial C / \partial v = C/v$, so (17) becomes

$$(18) \quad -\partial \ln C_T / \partial t = (p_m m / C_T) (\partial \ln \psi / \partial t) + (C / C_T) (\partial \ln v / \partial t),$$

giving us

Result 5. If the value-added function in a quasi-fixed-proportions technology has constant returns to scale, the dual rate of productivity growth is the sum of the primal rates of productivity growth in materials and in value added, each weighted by its proportional share in total cost.

Because, in addition, the I sub-technologies in (4) generally differ from one another, a firm's true multifactor productivity growth rate must be an average of the growth rates in the individual sub-technologies. Unfortunately, analysts do not ordinarily compute aggregate productivity growth rates in such fashion. Instead, they normally form an index of the output and of each of the inputs, then assume that the output index is determined by an output-separable function of the input indexes and time. For example, where value-adding inputs are capital (k_i) and labor (l_i), the analyst constructs indexes $q = q(q_i, \forall i)$, $m = m(m_i, \forall i)$, $k = k(k_i, \forall i)$, $l = l(l_i, \forall i)$, then regresses

$$(19) \quad q = g(m, k, l, t),$$

from which multifactor productivity growth is computed as $\partial \ln g / \partial t$.

To see the general error of doing so, assume for illustration that all inputs are allocable, so that the technology (4) from which q_i, m_i, k_i, l_i are drawn is nonjoint. Hall

[1973] showed that a multiproduct technology cannot be both nonjoint and output-separable unless the sub-technologies are essentially identical to one another. Thus, in order for (4), and by extension (16) and (19), to be both nonjoint and output-separable, it must by Hall's theorem consist of a set of identical sub-technologies, an improbable event. There is no reason to think that incorporating unallocable inputs would relieve this misspecification.

How severe is the likely bias if productivity growth is measured from aggregate model (19) rather than from disaggregate, quasi-fixed-proportion models (16)? To answer this, I conducted a Monte Carlo analysis of productivity growth in four outputs, each with production structure (16). Value-added functions v_i were assumed Cobb-Douglas with constant returns to scale: $\ln v_i = \eta_{oi} + \eta_{ki} \ln k_i + (1 - \eta_{ki}) \ln l_i + \beta_i t + \eta_i$, where $\eta_i \sim N(0, \sigma_\eta^2)$. Material transformation functions were log-linear also: $\ln(m_i \psi_i) = \ln m_i + \ln \psi_i + \delta_i t + \xi_i$, in which $\xi_i \sim N(0, \sigma_\xi^2)$ is independent of η_i . Parameter estimates were obtained using 1958 - 1989 BLS data from the U. S. meat processing, dairy, baking, and beverage industries (Gullickson and Harper).⁹

The true dual measure of productivity growth (1.8% per year) in the four industries regarded as a single sector was found by first forming the weighted mean productivity growth rate (18) in each industry, then averaging these rates, as weighted by the corresponding industry expenditure shares, over the four industries. The productivity growth measure which one instead would have derived from aggregate data was simulated by drawing randomly from each industry's error terms η_i and ξ_i during each modelled year 1958 - 1989, and constructing the associated industry output quantities from (16). Sector-level, that is aggregate, outputs and input demands were then formed as Tornqvist indexes of the industry-level quantities and equation (19) estimated with a translog functional form. In 10,000 repetitions of this process, mean aggregate growth rate $\partial \ln g / \partial t$ (at the 1973 midpoint) was 1.3% per year, 28% below the true growth rate of 1.8%. When industry parameters were

altered to increase the inter-industry differences among them, the growth rate measures derived from the aggregate data fell even further below the true rates.¹⁰

5. Conclusions

At the most disaggregate level of a manufacturing firm's operations, the assembly line for an individual good, an intermediate material cannot have a marginal product. It can instead be valued only by reference to its marginal net revenue products, which reflect the material's contributions to the net returns of adjacent product lines. The substitutability often observed in aggregate models between material and value-adding inputs represents just such an exchange of material for capital and labor as the firm adjusts its output plan across alternative products. Indeed, sector models in which materials are permitted to substitute for capital and labor are essentially reduced-form versions of the disaggregate model developed here (Griliches and Lichtenberg [1984], Jorgenson, Gollop, and Fraumeni [1987], Wohlgenant [1989], Norrbin [1993]).

As aggregation proceeds, the use of fully differentiable, unrestricted flexible forms becomes increasingly appropriate because one is increasingly likely to observe full substitutability among all inputs. The aggregation level above which almost-nonjointness and quasi-fixed proportionality are no longer satisfied likely differs by manufacturing industry. Identifying these critical levels, and indeed verifying our hypothesis that such critical levels exist, is an empirical issue. Yet even when it involves no statistical efficiency loss, the use of unrestricted flexible forms masks the source of substitution between materials and value-adding factors. Ignoring restrictions such as (4), therefore, compromises many of the purposes, such as material valuation and productivity growth rate inference, for which production models are intended to be useful.

Appendix A

The sufficiency portion of Result 1 is proved by noting that the cost minimization problem corresponding to (7) is the same as in (5) but with constraints

$$(A.1) \quad q_i^\circ = (\sum_j m_{ij})^\circ \leq \text{Min } [g_i(\mathbf{x}_i), t_i(\mathbf{z})] \quad (i = 1, \dots, I).$$

instead of $q_i^\circ \leq v_i(\mathbf{x}_i, \mathbf{z})$. Assuming an interior solution, the Lagrangian of such a problem is

$$(A.2) \quad L_2 = \sum_i \mathbf{p}_i \mathbf{x}_i + \mathbf{p}_z \mathbf{z} - \sum_i \delta_i [g_i(\mathbf{x}_i) - q_i] - \sum_i \gamma_i [t_i(\mathbf{z}) - q_i]$$

with first-order conditions

$$(A.3) \quad p_x^k = \delta_1 \partial g_1(\mathbf{x}_1) / \partial x_{k1} \quad (k = 1, \dots, K)$$

$$q_1 \leq g_1(\mathbf{x}_1)$$

$$\delta_1 [g_1(\mathbf{x}_1) - q_1] = 0$$

Set 1

$$\delta_1 \geq 0$$

$$p_x^k = \delta_I \partial g_I(\mathbf{x}_I) / \partial x_{kI} \quad (k = 1, \dots, K)$$

$$q_I \leq g_I(\mathbf{x}_I)$$

$$\delta_I [g_I(\mathbf{x}_I) - q_I] = 0$$

Set I

$$\delta_I \geq 0$$

$$\begin{aligned}
p_z^n &= \sum_i \gamma_i \partial t_i(\mathbf{z}) / \partial z_n & (n = 1, \dots, N) \\
q_i &\leq t_i(\mathbf{z}) & (i = 1, \dots, I) \\
\sum_i \gamma_i [t_i(\mathbf{z}) - q_i] &= 0 & \text{Set U} \\
\gamma_i &\geq 0 & (i = 1, \dots, I)
\end{aligned}$$

The $I + 1$ independent sets of equations in (A.3) form the first-order conditions of

$$\begin{aligned}
\text{(A.4)} \quad C_{al,i}(\mathbf{m}_i, \mathbf{p}_x) &= \text{Min (wrt } \mathbf{x}_i) L_{xi} = \mathbf{p}_x \mathbf{x}_i - \delta_i [g_i(\mathbf{x}_i) - q_i] \\
&\vdots \\
C_{al,I}(\mathbf{m}_I, \mathbf{p}_x) &= \text{Min (wrt } \mathbf{x}_I) L_{xI} = \mathbf{p}_x \mathbf{x}_I - \delta_I [g_I(\mathbf{x}_I) - q_I] \\
C_{un}(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_z) &= \text{Min (wrt } \mathbf{z}) L_z = p_z z - \sum_i \gamma_i [t_i(\mathbf{z}) - q_i]
\end{aligned}$$

respectively, where $C_{al,i}(\mathbf{m}_i, \mathbf{p}_x)$ is the cost of the i^{th} product's allocable inputs and $C_{un}(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_z)$ is the cost of the unallocable inputs, that is of overhead. With technology (7) then, we have

$$(5') \quad C(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_x, \mathbf{p}_z) = \sum_i C_{al,i}(\mathbf{m}_i, \mathbf{p}_x) + C_{un}(\mathbf{m}_1, \dots, \mathbf{m}_I, \mathbf{p}_z).$$

Total cost of the value-adding inputs is the sum of the minimized costs of each product's allocable inputs plus the minimized overhead cost. Overhead cost minimization is independent of allocable cost minimization.

The necessity portion of Result 1 follows from the fact that Lagrangian form (A.2), which is additive in $\mathbf{x}$ and $\mathbf{z}$ and which therefore permits cost independence (A.4), arises only if the technology constraints are of quasi-Leontief form (A.1). ◀

Because each of sets 1, ..., I in (A.3) is a classical single-product optimization, each restriction $q_i \leq g_i(\mathbf{x}_i)$ will be a strict equality and $\delta_i > 0, \forall i$; that is, each product's marginal

cost of allocable inputs is positive. In the unallocated set (U), on the other hand, only one of the I restrictions $q_i \leq t_i(\mathbf{z})$ need be tight in the optimal solution $\mathbf{z}^*$. By complementary slackness, the corresponding multipliers γ_i are zero. Result 2 follows immediately.

For illustration, consider the case $I = N = 2$. The set of unallocable inputs solving Block U of (A.3) is $\{\min_{\mathbf{z}} \mathbf{p}_z \mathbf{z} \mid t_1(\mathbf{z}) \geq q_1, t_2(\mathbf{z}) \geq 0\}$. To find this set, first find $A = \{\min_{\mathbf{z}} \mathbf{p}_z \mathbf{z} \mid t_1(\mathbf{z}) \geq q_1\}$ and $B = \{\min_{\mathbf{z}} \mathbf{p}_z \mathbf{z} \mid t_2(\mathbf{z}) \geq q_2\}$. Evaluate $t_2(\mathbf{z})$ at A. If $t_2(\mathbf{z}) \geq q_2$ is satisfied, then A is the optimal solution $\mathbf{z}^*$ to $\{\min_{\mathbf{z}} \mathbf{p}_z \mathbf{z} \mid t_1(\mathbf{z}) \geq q_1, t_2(\mathbf{z}) \geq 0\}$. If A does not satisfy $t_2(\mathbf{z}) \geq q_2$, check to see if B satisfies $t_1(\mathbf{z}) \geq q_1$. If it does, B is the optimal solution $\mathbf{z}^*$. If it does not, the optimum is found by solving $t_1(\mathbf{z}) = q_1, t_2(\mathbf{z}) = 0$ for $\mathbf{z}^*$. The latter solution occurs at a corner, and tangency condition $p_z^1/p_z^2 = (\partial v/\partial z_1)/(\partial v/\partial z_2)$ does not hold.

Appendix B

To derive equation (17), note that the total cost of the i^{th} product line is, ignoring i subscripts,

$$(B.1) \quad C_T = p_m m + C(v, \mathbf{p}_x, \mathbf{p}_z)$$

where $p_m m$ is cost of materials and C is cost of value-added. From equation (16), the cost-minimizing firm sets $m\psi = v$. Hence, we can rewrite (B.1) as

$$(B.2) \quad C_T = p_m (v/\psi) + C(v, \mathbf{p}_x, \mathbf{p}_z).$$

Differentiating (B.2) partially with respect to time, that is holding m , v , and input prices constant, gives the dual rate of multifactor productivity growth (Morrison [1992]):

$$\begin{aligned} \partial C_T / \partial t &= - (p_m v / \psi^2) (\partial \psi / \partial t) + \partial C / \partial t \\ &= - (p_m m / \psi) (\partial \psi / \partial t) - (\partial C / \partial v) (\partial v / \partial t). \end{aligned}$$

Dividing by C_T ,

$$(B.3) \quad - \partial \ln C_T / \partial t = (p_m m / C_T) (\partial \ln \psi / \partial t) + [(\partial C / \partial v) / C_T] (\partial v / \partial t).$$

Multiplying the right-most expression of (B.3) by v/v gives the version in equation (17):

$$(B.4) \quad - \partial \ln C_T / \partial t = (p_m m / C_T) (\partial \ln \psi / \partial t) + (\partial C / \partial v) (v / C_T) (\partial \ln v / \partial t),$$

Observe that $\partial \ln(m\psi) / \partial t = d \ln(m\psi) / dt - \partial \ln m / \partial t = \partial \ln \psi / \partial t$ in (B.4) is the primal rate of productivity growth in material transformation function $m\psi = q = v$, namely the rate of change in material transformation parameter ψ , holding total material input m fixed.

Footnotes

1. Although alternative raw material proportions and industrial treatments might in some cases generate the same characteristics vector c_i , the likelihood of such an occurrence diminishes as product characteristics are examined more finely.
2. Inasmuch as m and x are perfectly allocable input vectors, eliminating z from (4) would leave a nonjoint-in-inputs technology, in which there is no incentive to operate a multiproduct firm. In contrast, eliminating allocable inputs x reduces (3) to the nonjoint-in-input-prices form $q_i \leq v_i(z)$, $i = 1, \dots, I$, and thus reduces (4) to $q_i = \text{Min} [m_{i1}/s_{i1}, \dots, m_{iJ}/s_{iJ}, v_i(z)]$; $i = 1, \dots, I$; $\sum_i m_i = m$. Each product quantity would then be limited by common inputs like plant lighting and management, although marginal effects of such inputs differ across products.
3. Problem (5) assumes that price p_x^k of the k^{th} allocable input is unaffected by the input's allocation among products.
4. Expressed differently, equations (6c) say that the price of a public input is the sum of the input's value contributions to the different product lines. Kohli (p. 389) has derived an equivalent condition for a variable (allocable) cost function.
5. "The most difficult and interesting part of the overall problem is that of finding the optimum configuration for a specified number of goods" (Lancaster, p. 576).
6. Proportionate shares are collectively interdependent because they sum to one. Yet the j^{th} share, s_{ij} , is independent of changes in the j'^{th} share provided a j'^{th} material exists whose share can be altered to compensate for changes in the j'^{th} . For this reason, it is not tautological to distinguish between the effects of separate material shares.

7. Substituting $\partial s_{ij}/\partial m_{ij} = (q_i - m_{ij})/q_i^2$, $j' = j$, and $\partial s_{ij}/\partial m_{ij} = -m_{ij}/q_i^2$, $j' \neq j$, into (11) gives

$$\begin{aligned} \partial \pi / \partial m_{ij} = & p_i - \partial C / \partial q_i \\ & + q_i \{ (\partial p_i / \partial s_{i1}) [-m_{i1}/q_i^2] + \dots + (\partial p_i / \partial s_{ij}) [(q_i - m_{ij})/q_i^2] \\ & + \dots + (\partial p_i / \partial s_{iJ}) [-m_{iJ}/q_i^2] \} \\ & - (\partial C / \partial s_{i1}) (-m_{i1}/q_i^2) + \dots + (\partial C / \partial s_{ij}) [(q_i - m_{ij})/q_i^2] \\ & + \dots + (\partial C / \partial s_{iJ}) (-m_{iJ}/q_i^2) \} \\ & - p_m^j. \end{aligned}$$

Kuhn-Tucker conditions for a profit maximum are: (i) $\sum_i \sum_j [\partial \pi / \partial m_{ij}] m_{ij} = 0$; (ii) $m_{ij} \geq 0$, $\forall i, j$; and (iii) $\partial \pi / \partial m_{ij} \leq 0$, $\forall i, j$, implying $\partial R / \partial m_{ij} \leq p_m^j$. Collecting derivatives with respect to each s_{ij} and requiring $\partial \pi / \partial m_{ij} \leq 0$ for optimality gives expression (12).

8. This is true even in the case of separable technology (7), since by virtue of the third equation in Set U of Appendix A, altering the i^{th} output quantity generally changes the marginal cost of the i^{th} product.
9. The BLS data correspond to industry aggregates rather than to individual assembly lines and are used here only to provide reasonable parameter benchmarks. Because of the benchmarks' industry-level origin, and because the simulation represents aggregation from a given level to the next higher one, I have cast it for rhetorical purposes as an aggregation from the industry to sector (multi-industry) level. I do not imply that industry-aggregate technologies are well described by equation (4) or (18). Real-world aggregate data are summations over numerous operating levels (from assembly line to plant to firm and so forth), and the present simulation is meant to be

suggestive only.

10. In the base solution, capital output elasticities η_{ki} ranged from 0.11 (in the dairy industry) to 0.24 (in the beverage industry). Material transformation rates ψ_i ranged from 0.94 to 0.99.

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CHEPTER 2: PRODUCTIVITY MEASUREMENT IN THE AGRICULTURAL MARKETING SECTOR

In his 1975 AAEA principal paper, Laurits Christensen complained of the excessive attention that productivity researchers were lavishing on capital and labor, ignoring, in their zeal, Domar's words that "it must take some ingenuity to make potato chips without potatoes." Today, most productivity studies do pay heed to intermediate inputs, including raw and semi-processed materials, packaging, and energy. Yet the mechanism whereby materials interact with value-adding factors to generate productivity growth has never been clearly spelled out. In particular, little effort has been made to reconcile the standard production model, in which output is separable and materials enter symmetrically with capital and labor, with micro-level production technologies that are manifestly output-nonseparable and asymmetric.

In the present paper, we try to make some progress in these directions. We begin by proposing a multiproduct form of Diewert's generalized Leontief framework. We impose structure on this framework to reflect manufacturing operations in general and food processing in particular. We then show the implications of such a structure for productivity modelling at the sectoral level. Our principal finding is that separable production functions commonly used to assess aggregate productivity growth are misspecified, and that productivity growth measures themselves are generally biased. Monte Carlo evidence suggests the bias can be large, although predicting the magnitude and direction of bias will often be difficult.

Micro-Technology and Aggregation

Aggregating microeconomic data to an SIC two-digit level such as food processing is a stepwise affair, from assembly lines through plants, firms, then increasingly generic product categories. An index observation at any aggregation level depends on the technological structure assumed to prevail in the data from which the aggregation has immediately proceeded. Thus, aggregation issues are specific to the aggregation step in question. To simplify matters, we will focus on the implications of assembly line technology for sector-level aggregates, ignoring the complications presented by intermediate steps.

A manufacturing assembly line, on which a particular good is produced with given technology, can in a broad way be characterized as

$$(1) \quad Q_i = F_i (M_i, K_i, L_i, t), \quad i = 1, \dots, I,$$

where i indexes the assembly line; Q is output; M, K, L are materials, capital, and labor; and t is time. More specifically, however, a manufactured product is defined by the proportions of the materials constituting it and by the industrial process used to add value to the materials. Industrial processes require capital and labor, which may be combined in a number of ways to produce a given quantity of value-added. On a given assembly line, therefore, materials and value-added enter in fixed proportions. These facts can be represented in Diewert's generalized Leontief model (pp. 497 - 505) by setting to zero the cross-product coefficients between material and nonmaterial inputs, giving the quasi-fixed proportions model $Q = \text{Min} [M\alpha, V(K, L)]$, where α is the proportion of materials surviving in the final product and V is the value-added function.

Heien (1980, p. 11) and Brorsen et al. (p. 523) have used quasi-fixed proportions in their studies of food marketing margins.

Diewert's framework can easily be generalized to include multiple products and multiple technologies for a given product. Consider the form

$$(2) \quad Q_i = \text{Min} [M_i \alpha_i(\beta_i, t), V(K_i, L_i, t; \beta_i)], \quad i = 1, \dots, I.$$

A parameter vector β_i , specific to the i^{th} assembly line, determines in a given period not only the capital and labor combinations which generate a given quantity of value-added, but the proportion α_i of raw material recoverable in the final product. Thus, for example, extraction technology in olive oil production influences the oil-to-olive ratio as well as the capital-labor combinations producing a fixed quantity of value-added. Separate time trends in (2) permit distinct technical change rates in value-added and material transformation functions.

Framework (2) can be used to characterize a set of i -indexed goods or technologies in a single multiproduct firm, or a set of i -indexed firms producing related goods in a particular manufacturing sector. The multiple-firm version here is input-nonjoint; in a single-firm application, one may relax the nonjointness by adding non-indexed (unallocable) inputs. Each equation in (2) is output-separable; yet (2) as a whole is nonseparable as long as parameters β_i differ across product lines.

The typical primal method of assessing aggregate productivity growth is to form indexes $Q = Q(Q_i, v_i)$, $M = M(M_i, v_i)$, $K = K(K_i, v_i)$, and $L = L(L_i, v_i)$, then regress

$$(3) \quad Q = G(M, K, L, t)$$

with a differentiable functional form. The proportionate rate of productivity growth, holding inputs M, K, L constant, is measured by

$$(4) \quad \partial \ln Q / \partial t = v(M, K, L, t).$$

If, however, (2) correctly reflects the micro-level environment, (3) cannot do so. Unlike (2), model (3) is differentiable and output-separable and ignores *a priori* information about the manner in which materials are employed in industrial production. These weaknesses suggest that productivity growth rates (4) are incorrectly specified.

Nature of Bias

To view the problem as broadly as possible, suppose first that disaggregated assembly-line production functions take the generic form (1). The Tornqvist index typically used as the dependent variable in aggregate model (3) is $Q = \ln Q_t - \ln Q_0 = (1/2) \sum_i (S_i + S_i^0) (\ln F_i - \ln F_i^0)$, where $S_i \equiv P_i Q_i / \sum_i P_i Q_i$ is value share, P_i is output price, and 0 superscripts denote base period. Substituting (1) into this index, differentiating according to (4), and taking the limit as $\partial t \rightarrow 0$ [so that $(\ln F_i - \ln F_i^0) \rightarrow d \ln F_i / dt$ and $(1/2)(S_i + S_i^0) \rightarrow S_i$], gives

$$(5) \quad \partial \ln Q / \partial t = \sum_i S_i \partial \ln F_i / \partial t + \sum_i (\partial S_i / \partial t) d \ln F_i / dt.$$

The sectoral productivity growth rate derived from the usual output-separable aggregate model is the share-weighted average of the productivity growth rates in the individual product lines plus a bias factor. The bias is the sum of changes in output shares induced by the productivity growth times the corresponding *total* rates of output growth.

More specifically, what if framework (1) takes quasi-fixed-proportions form (2), which we argue is typical of food manufacturing enterprises? Model (2) presents two problems: (i) it isn't differentiable, and (ii) productivity growth in the material function may differ from that in the value-added function. We can get around these difficulties by using the dual ~~version~~ ^{productivity growth rate, which under CRTS can be expressed as} $-\partial \ln c / \partial t = \partial \ln F / \partial t$, ^{where} ~~of the productivity growth rate, in which~~ c is unit total cost. It can be shown that $-\partial \ln c / \partial t = (P_m / \alpha c)(\partial \ln \alpha / \partial t) + (P_v / c)(\partial \ln V / \partial t)$, where P_m is the material price, P_m / α is the marginal cost of materials, and P_v is the marginal cost of value-added. Substituting $-\partial \ln c / \partial t$ for $\partial \ln F_i / \partial t$ in (5) gives

$$(6) \quad \begin{aligned} \partial \ln Q / \partial t = & \sum_i S_i [(P_{mi} / \alpha_i c)(\partial \ln \alpha_i / \partial t) + (P_{vi} / c)(\partial \ln V_i / \partial t)] \\ & + \sum_i (\partial S_i / \partial t) \ln(M_i \alpha_i) / dt. \end{aligned}$$

True productivity growth (first right-hand term) is the share-weighted sum across product lines of the marginal-cost-weighted sum of each product's productivity growth rate in materials and in value-added. Productivity growth rate estimates in aggregate, output-separable models will reflect, in addition to this true rate, the weighted sum of total output growth, which in turn equals the total growth rate either of usable materials or of value-added. Productivity change is again confounded with total output growth.

Because cost-minimizing firms adjust input levels continuously to ensure that $d \ln(M\alpha) / dt = d \ln V / dt$, we can examine the bias in (6) by way of either the material transformation or value-added function. Consider, for example, the material transformation function: its total growth rate $d \ln(M\alpha) / dt$ equals $\partial \ln M / \partial t + \partial \ln \alpha / \partial t$, so that the bias in the aggregate growth rate estimate is affected by the growth rate $\partial \ln M / \partial t$ in the quantity M of the conventional material input as well as by the rate of growth $\partial \ln \alpha / \partial t$ in material productivity. By the same token, bias is affected by the

growth of capital and labor inputs as well as by the rate of productivity growth in the production of value-added.

The second line of (6) is zero if $d\ln(M_i\alpha_i)/dt = d\ln V_i/dt$ is constant across product lines, inasmuch as $\sum_i (\partial S_i/\partial t) = 0$. Hence, the bias in aggregate, output-separable models vanishes if and only if product lines' total growth rates equal one another. Such equality can be maintained globally only if one product's parameter vector β_i is the same as the next one's. In that event, productivity growth (6) is unambiguously $[(P_m/\alpha c)(\partial \ln \alpha/\partial t) + (P_v/c)(\partial \ln V/\partial t)]$, which is common across firms. Hall's (p. 891) proof, that a multiproduct technology cannot be both nonjoint and separable unless the several production functions are essentially identical, established this conclusion in more general form twenty-three years ago. Absent externalities, firms' technologies are nonjoint of one another. Yet regressing a cross-firm aggregate of outputs against a cross-firm aggregate of inputs assumes the existence of a single, separable production technology. Being both nonjoint and separable, such a technology must by Hall's theorem consist of a set of firm-wise-identical production functions.

Assessing the Extent of Bias

Aggregate productivity growth measures are subject to bias because, in the presence of heterogeneous assembly line technologies, input or output price changes induce substitution across products in a given output index. Substitution assures that output growth will be confounded with productivity growth. Thus also, the magnitude of bias depends on magnitudes of cross-product differences in parameter vector β_i and on the sizes of relative price changes. To obtain a sense of the estimation bias researchers are likely to encounter, we conducted a Monte Carlo analysis of aggregate productivity

growth of four micro production units, each with production structure (2). Value-added functions V were assumed Cobb-Douglas with constant returns to scale: $\ln V_i = \eta_{oi} + \eta_{ki} \ln K_i + (1 - \eta_{ki}) \ln L_i + \gamma_i t + \epsilon_i$, where $\epsilon_i \sim N(0, \sigma_{\epsilon_i}^2)$. Material transformation functions were log-linear also: $\ln(M\alpha)_i = \ln M_i + \ln \alpha_i + \delta_i t + u_i$, in which $u_i \sim N(0, \sigma_{u_i}^2)$ is independent of ϵ_i . Parameter estimates were obtained using 1958 - 1989 BLS data from the meat processing, dairy, baking, and beverage industries (Gullickson and Harper). Output elasticities of capital (0.12, 0.11, 0.18, and 0.24, respectively) were low, perhaps because quasi-fixed-proportions model (2) is more appropriate at the assembly-line than at the industry level. However, the estimates do provide a notion of inter-industry technology differences, and act as a base point for sensitivity analysis.

Conditional capital and labor demand quantities were derived by substituting capital and labor price time series into the conditional demand functions derived from the Cobb-Douglas technology (Varian, p. 55). Conditional material demands were obtained by solving $\ln(M\alpha)_i$ for $\ln M_i$. Unconditional demands were then found by evaluating conditional demands at expected outputs as determined by linear trend fits to the actual output series. Substituting unconditional demands M_i^* , K_i^* , L_i^* into the value-added and material transformation functions gave minimum outputs $\ln(M\alpha)_i^*$, $\ln V_i^*$ in each industry and year. Following (2), realized outputs were then calculated as $\ln Q_i = \text{Min} [\ln(M\alpha)_i^*, \ln V_i^*]$, a function of random variables ϵ_i , u_i as well as of the factor demands. Finally, Tornqvist indexes Q , M , K , and L were formed from the realized outputs and inputs in each of the simulated years 1958 - 1989, and these were used to fit a translog functional form to sector model (3). By drawing successively from random variable distributions $N(0, \sigma_{\epsilon_i}^2)$ and $N(0, \sigma_{u_i}^2)$, we derived successive sets of translog regressions, from which histograms of aggregate parameter estimates were obtained.

Results

Table 1 gives the chief simulation results. The third-from-right column lists the sample mean of the estimated aggregate productivity growth rates (4) generated by 10,000 successive draws on industry-level random errors ϵ_i , u_i . (Error variances $\sigma_{\epsilon_i}^2$ and $\sigma_{u_i}^2$ were set at 0.00001 in all simulations.) The second-from-right column lists, by contrast, the true mean sectoral productivity growth rate, namely the mean of the individual productivity growth rates in the four industries. To construct this true mean sectoral rate, we first calculated the marginal-cost-weighted average of the value-added productivity growth rate γ_i and material productivity growth rate δ_i in each industry. We then weighted each industry's average productivity growth rate by that industry's market share and summed these over the four industries. Finally, the right-hand column of table 1 shows the deviation between the mean aggregate and true productivity growth rates.

Output elasticities and material transformation rates in scenario 1 of table 1 are those we estimated from the BLS data. Scenarios 2 through 10 assume greater inter-industry technological heterogeneity than in the scenario 1 base case. In scenario 2, material transformation rates are more heterogeneous than in the base, while output elasticities remain unchanged. In scenario 3, output elasticities are varied instead, while material transformation rates remain at base levels. Both sets of parameters are varied in scenario 4. Scenario pairs (5, 6), (7, 8), and (9, 10) differ from (3, 4) only in the assumed dispersion and order of the industries' output elasticities.

Since inter-industry parameter variability is higher in scenarios 2 - 10 than in scenario 1, we hypothesize that the (absolute values of) mean bias terms should be higher in scenarios 2 - 10 also. With only one exception, this hypothesis is substantiated.

Holding parameters at scenario 1 levels, the annual productivity growth rate one expects to estimate using an aggregate model is 1.3%, compared to the true mean growth rate of 1.8%. One expects, in other words, a negative bias of one-half percentage point if one uses the aggregate translog model when parameters are at scenario 1 levels. At the 1973 mid-point of the 1958 - 1989 sample range, this represents an error of -\$129.50 million (\$496.64 million in 1996 dollars) in the imputed revenue effects of productivity growth. Only in scenario 3 is the absolute mean bias lower than in this base case. Average mean bias in scenarios 2 - 10 is -0.9%, implying the analyst should expect to understate the true productivity growth rate by nearly one percentage point.

Inter-industry differences in material transformation rates have a more substantial effect on mean bias than do inter-industry differences in value-added parameters. Indeed, the bias-enhancing effect of inter-industry parameter heterogeneity in table 1 may be due entirely to the heterogeneity of material transformation rates. We regressed mean bias (B) against the standard deviation of the four capital output elasticities (S_v) and the four material transformation rates (S_m), obtaining $B = -0.69 + 1.06 S_v - 5.39 S_m$, with standard errors 0.21, 1.10, 1.68, respectively. S_v is nonsignificant, suggesting parameter heterogeneity in industry-level value-added functions has little influence on bias. These results are specific to the ten observations in table 1 and do not constitute an inference about population parameters.

Because of random errors in micro-level production units, productivity growth rates estimated from aggregate data will be stochastic. Figure 1 shows the frequency distribution of aggregate-model productivity growth rates when technology parameters are at scenario 1 levels. The figure shows there are substantial probabilities of obtaining growth rate estimates well above or below the true growth rate of 1.8%. For example,

the analyst has a 40% chance of concluding that productivity has declined, even though the true growth rate was positive. Jorgenson, Gollop, and Fraumeni (p. 487) estimate that productivity growth in the Food and Kindred Products industries was negative during 13 of the 22 years between 1948 and 1979, and Heien (1983, p. 301) infers there were 15 negative growth years between 1950 and 1977. One wonders how many of these negative rates reflected error variances in the individual industries comprising the aggregate.

We had no way of guessing whether the stochastic mixing involved in each industry's input minimization process (2) would result even in a unimodal aggregate frequency. Yet the productivity growth rate distribution in figure 1 is approximately bell-shaped, with perhaps a slight rightward skew. The distributions corresponding to scenarios 2 - 10 were nearly bell-shaped also. A central limit theorem undoubtedly accounts for these shapes; approximate bell forms were not achieved until we increased the number of random draws above 1000.

In sum, evidence from the meat processing, dairy, baking, and beverage industries suggests that sectoral productivity growth rates derived from aggregate models will often be substantially negatively biased. Increasing heterogeneity of micro-level technologies -- especially in material transformation rates -- appears generally to increase mean bias. However, these results are highly preliminary, subject as they are to sampling error and to the specific parameters employed. The complexity of the table 1 results dramatizes our model's highly nonlinear nature and suggests that extrapolating the bias effects of individual parameter changes will be difficult. Aggregation bias in productivity growth rate estimates is a specification-intensive subject deserving much greater study than it has received in the past.

Table 1. Biases in Aggregate Productivity Growth Rate Estimates, Given Alternative Micro-Level Technologies^a

Scenario	Micro-Level Technology Parameters		Productivity Growth Rate Estimates (%)		
	Output Elasticities of Capital(η_{ki})	Base-year Material Transformation Rates (α_i)	Mean Aggregate	True Weighted Mean	Mean Bias
1	0.12, 0.11, 0.18, 0.24	1.00, 0.94, 0.99, 0.99	1.3	1.8	-0.5
2	0.12, 0.11, 0.18, 0.24	0.50, 0.60, 0.70, 0.80	0.6	1.6	-1.0
3	0.20, 0.40, 0.60, 0.80	1.00, 0.94, 0.99, 0.99	1.5	1.9	-0.4
4	0.20, 0.40, 0.60, 0.80	0.50, 0.60, 0.70, 0.80	0.9	1.7	-0.8
5	0.80, 0.60, 0.40, 0.20	1.00, 0.94, 0.99, 0.99	1.4	2.1	-0.7
6	0.80, 0.60, 0.40, 0.20	0.50, 0.60, 0.70, 0.80	0.8	1.9	-1.1
7	0.10, 0.20, 0.30, 0.40	1.00, 0.94, 0.99, 0.99	1.0	1.8	-0.8
8	0.10, 0.20, 0.30, 0.40	0.50, 0.60, 0.70, 0.80	0.2	1.6	-1.4
9	0.40, 0.30, 0.20, 0.10	1.00, 0.94, 0.99, 0.99	1.0	1.9	-0.9
10	0.40, 0.30, 0.20, 0.10	0.50, 0.60, 0.70, 0.80	0.3	1.7	-1.4

^a Parameters not listed in columns (2) and (3) are fixed as follows (for meat, dairy, baking, and beverages, respectively). η_{oi} : 1.10, 0.91, 1.05, 0.92. γ_i : 0.02, 0.04, 0.01, 0.40. δ_i : 0.01, -0.001, 0.001, 0.001. $\sigma_{ei}^2 = \sigma_{ui}^2 = 0.00001$. Parameters shown in columns (2) and (3) refer to the meat, dairy, baking, and beverage industries, respectively.

^a Numbers on x-axis refer to the upper boundaries of the respective intervals.

Figure 1. Histogram of Productivity Growth Rate Estimates Derived from Aggregate Translog Model

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CHAPTER 3: AGRICULTURAL COOPERATIVE IN RISKY COMPETITIVE ENVIRONMENT

1. Introduction

This paper integrates two important factors in agriculture: cooperation and risk. Agricultural cooperatives appear in many forms and are common to many countries. For example, production cooperatives had emerged mainly in the eastern centrally-planned economies, while processing and marketing cooperatives could often be found in free western economies. Obviously there are critical differences in terms of economic efficiency and incentive structure between cooperatives and, the so-called, capitalistic firms. To name a few, cooperative structure allows easier exertion of market power, utilization of scale and scope advantages, adoption of new technologies, and risk pulling. On the other hand, in many cases, it suffers from adverse-selection, moral hazard, free riding and other incentive problems. A question regarding the role and importance of cooperatives in the agricultural sector then arises. In other words, is cooperation in agriculture advantageous? Clearly, the evolution of agricultural cooperatives in free economies such as in the United States provide supporting evidence. Even more supportive is the continuing existence of agricultural cooperatives in the former Soviet Union, more than ten years after the implementation of economic liberalization there.

It is well known that firms within the agricultural sector are subject to high risks. This is mostly due to the vulnerability of agricultural production to adverse weather conditions, which lead to aggregate yield fluctuations and which in turn induce price variations. The existence of agricultural cooperatives operating in a risky competitive environment provides the initial motivation for the study of the effects of risk and risk aversion on industry equilibrium and the cooperative supply decisions involved. These objectives gain importance in light of the well accepted fact that the agricultural sector, in many developed nations, is subject to some governmental intervention. The latter is justified since most agricultural activities to some degree involve negative, as well as positive, externalities.

This paper adds to the evolving literature regarding agricultural cooperatives in general (*i.e.* Csaki and Kislev (1993), Buccola (1991), Zusman (1982)) and under risky environment in particular (*i.e.* Machnes and Schnytzer (1993)). The latter authors studied

production cooperatives in the former Soviet Union and focused on risk as a factor which may explain the survival of collective farms even after the collapse of the communist polity. A difference worth mentioning exists between production cooperatives and processing cooperatives which are modeled here. Production outside of the cooperative involves risk while the alternative to cooperative processing is marketing at on-going market prices.

Moreover, as observed by Sexton (1984) LMFs "are closely analogous to agricultural marketing cooperatives. Cooperatively processing and marketing the raw labor input is conceptually very similar to processing and marketing a raw agricultural commodity such as milk or grain." (p. 429). Specifically, he noted that the LMF theorists explore the same range of solutions as those developed by the agricultural cooperative theorists. Therefore, the theory developed in this paper also contributes to the analysis of LMF industry equilibrium.

Our analysis is built on the literature dealing with labor-managed firms (LMFs) operating under uncertainty. The initial motivation for the analysis of LMFs was mostly derived from an interest in the Yugoslavian experiment of self-managed firms which started in the early forties. To explain the behavior of these firms a theory of a LMF under certainty was developed by Ward (1958). It has since then been extended and tested empirically by many others, (for review and references see Bonin *et al.* (1993)). Important contributions, in the area of LMF behavior under uncertainty, include Muzondo (1979), Bonin (1980), Paroush and Kahana (1980), Hey and Suckling (1980) and Hey (1981) who consider the short-run in which labor is the only variable input. Later, the analysis has been extended to include the long-run behavior of a single LMF by Horowitz (1982), Kahana and Paroush (1984), Choi and Feinerman (1991) and Haruna (1993). Haruna (1988), on the other hand, examined some properties of LMF industry equilibrium.

This paper proposes an equilibrium analysis of an industry consisting of cooperatives in the presence of uncertainty. We make use of the expected utility model as the theory of choices and begin with the model specifications in section 2. Section 3 characterizes the entry/exit decisions of a single cooperative under price risk. The comparative static analysis is presented in section 4. Concluding remarks end the paper.

2. Modeling Cooperative Decisions Under Price Risk

The following presents a general approach for comparing firms with variations in risk attitudes. Thereafter, a model for production decisions of an agricultural cooperative under price risk is presented and several properties of the conditional demand and cost functions are examined.

Inter-firm Comparisons of Risk Attitudes

A convenient and general approach for comparing individuals with different risk attitudes was introduced by Diamond and Stiglitz (1974). We follow their approach in our analysis of agricultural cooperatives, beginning with a definition.

Definition An Increase in Risk Aversion: Consider a family of utility functions $U(\epsilon, \rho)$, where ϵ is a random variable affecting utility and ρ is a parameter representing the degree of risk aversion. An increase in ρ is said to represent an increase in risk aversion if and only if

$$-\frac{\partial^2 \log U_\epsilon}{\partial \epsilon \partial \rho} > 0,$$

that is, the index of absolute risk aversion is increasing with ρ . Diamond and Stiglitz showed that this is equivalent to the following: a) an increasing Pratt risk premium with ρ ; b) that a mean utility preserving increase in risk is disliked by the more risk averse individuals, *i.e.* individuals with higher ρ ; and c) that a higher ρ , but identical indifference curves, is equivalent to a concave transformation of the utility function.

Below we will assume that the utility function is differentiable in ρ . Thus, to model the effect of an increase in risk aversion on the cooperative decisions, one simply needs to differentiate the optimal decision with respect to ρ .

The Model

In the following description we keep in mind the case of a processing cooperative. Modifications for other types of cooperatives are not treated explicitly. The cooperative consists of many homogeneous members, each of which supplies the cooperative with the same mixture of raw agricultural products. The cooperative total profit is given by

$$\Pi(l, k, p, \tau, T) = pQ(l, k) - \tau k - T,$$

where l is total memberships reflecting the total amount of raw products processed by the cooperative,¹ k is an aggregate purchased input reflecting capital and other monetary expenses, r is the interest rate, T denotes fixed cost, and p denotes the random output price which is parameterized as

$$p \equiv \mu + \gamma\xi,$$

where $E(\xi) = 0$, $V(\xi) = 1$, and $\mu = h(S, \beta)$. The function h decreases with S – the total industry output, and increases with β – a demand shifter (*e.g.* an immigration wave or taste change). Finally, $E(\epsilon) = 0$ and $\gamma \geq 0$. The production function, $Q(l, k)$, is assumed to be concave and non-decreasing in both l and k .

The cooperative members choose l and k , *ex-ante*, so as to maximize the expected value of the von Neumann–Morgenstern utility function, U , defined over profits per member:

$$\max_{l \geq 0, k \geq 0} \int U[\pi(l, k, p, r, T), \rho] dF(p),$$

where $\pi = \Pi/l$ is the profit per member. The utility function $U(\pi, \rho)$ is assumed to be differentiable in the index of risk aversion, ρ , and twice differentiable, non-decreasing, and concave in π . The subjective cumulative distribution function of p , F , is assumed to have finite moments.

Employing the notion of a cost function, the cooperative choice problem could be described in an equivalent form, involving a two-stage solution. In the first stage, the optimal mix of l and k is chosen so as to minimize the cost per member for a given level of output per member, $q \equiv Q/l$. The minimal cost per member, to produce a given amount of output per member, is denoted by $C(q)$ and defined through the following minimization problem:²

$$C(q) \equiv \min_{l \geq 0, k \geq 0} \frac{rk + T}{l} \quad \text{s.t.} \quad \frac{Q(l, k)}{l} = q.$$

Focusing on an industry equilibrium we assume a long run planning horizon, namely the cooperative can optimally choose both inputs, k and l , in which case $T = 0$. However, for

¹ Note that in this model l may be treated as a continuous variable.

² Obviously, C is a function of r and T , as well. For the sake of clarity these parameters are subsumed.

the sake of completeness and comparison with previous studies, a short run analysis with fixed k and positive fixed cost will also be considered in the last section of the paper.

The necessary conditions for an interior solution of the above cost minimization problem are given by

$$(i) \quad r - \lambda Q_k = 0$$

$$(ii) \quad -rk - \lambda(Q_l l - Q) = 0$$

where subscripts of a function stand for partial derivatives with respect to the subscript and λ is the Lagrange multiplier. Further insight may be gained by combining these two conditions, yielding

$$Q_l l + Q_k k = Q.$$

This last condition is referred to as a local constant return to scale (CRS) condition. It states that at the optimum, the production function exhibits a CRS. As in the case of a capitalistic firm, if the production function of a cooperative is linearly homogeneous (exhibits global CRS), then the profit maximizing second-order conditions are not satisfied and equilibrium output is indeterminate. However, under CRS, the cost minimization problem of a capitalistic firm yields, in general, a unique solution, whereas the solution for the analogous problem of a cooperative is not unique (all input bundles that produce q cost the same).

The second stage of solving the cooperative problem is to utilize $C(q)$ for the maximization of expected utility, defined, as before, over profits per member. However, the choice variable in the second stage is the cooperative output per member, rather than the levels of the two inputs l and k . Formally, the second-stage of the cooperative optimization problem is given by

$$\max_{q \geq 0} \int U[pq - C(q)]dF(p).$$

The necessary condition for an interior solution of the above problem is given by

$$\int U_\pi \cdot [p - C_q(q)]dF(p) = 0.$$

The two-stage solution must be shown to be equivalent to the direct expected utility maximization with respect to the two inputs. As is formally shown in the appendix, this

assertion is valid since manipulation of the first-order conditions for the latter problem yields the necessary conditions for the former. On intuitive grounds, the two-stage solution is justified by the following reasoning: The choice of the input mixture does not affect the risk which the cooperative member faces. The latter is affected only by each member's level of output. Since the cooperative member's utility increases with π , the input mixture is chosen so as to minimize the cost per member for any given level of each member's output, independent of both price risk and risk attitudes. In the second stage, the level of output per member is chosen according to the members' risk preferences.

Properties of the Cost and Conditional Demand Functions

Under the assumption that the production function Q is concave, the cost function C is well defined and one can show several properties of C that will be useful below. These are formally stated in lemma 1.

Lemma 1: *Assuming that Q is concave,*

- (i) $C_q \geq 0$,
- (ii) $C_{qq} \geq 0$,
- (iii) $C_r \geq 0$,
- (iv) $C_T \geq 0$.

Properties (i) and (ii) have been proven by Hey (1981). Properties (iii) and (iv) are immediate.

The usefulness of lemma 2 in the equilibrium analysis which follows, lies in the fact that it describes the relationships between output per unit to inputs utilization and total output of the cooperative.

Lemma 2: *Let $\hat{l}(p)$, $\hat{k}(p)$ and $\hat{Q}(p)$ be the levels of input and output which maximize profit per unit when p is deterministic; and let $\check{l}(q)$, $\check{k}(q)$ and $\check{Q}(q)$ be the levels of input and output which minimize cost per member for a given level of of output per unit under*

uncertainty. Then

$$\begin{aligned} (i) \quad & \operatorname{sgn} \left(\frac{\partial \tilde{l}}{\partial q} \right) = \operatorname{sgn} \left(\frac{\partial \hat{l}}{\partial p} \right), \\ (ii) \quad & \operatorname{sgn} \left(\frac{\partial \tilde{k}}{\partial q} \right) = \operatorname{sgn} \left(\frac{\partial \hat{k}}{\partial p} \right), \\ (iii) \quad & \operatorname{sgn} \left(\frac{\partial \tilde{Q}}{\partial q} \right) = \operatorname{sgn} \left(\frac{\partial \hat{Q}}{\partial p} \right). \end{aligned}$$

Lemma 2 states that the effects of a change in output per member on inputs and output is qualitatively identical to the effect of a change in output price on them. Its power stems from the fact that the behavior of input demand and output supply with respect to output price under certainty, determines the relationships between output per unit to output and input use under uncertainty. The outline of the proof is given in the appendix. In addition, we note that when l and k are substitutes ($F_{lk} < 0$) / complements then ($F_{lk} > 0$) (i) is negative/indeterminate and (ii) is positive /indeterminate.

3. Entry and Exit Decisions of a Risk-Averse Cooperative

About two decades ago, in his seminal paper, Sandmo (1971) showed that a risk averse competitive firm facing output price risk requires a positive expected profit to remain in business. Following his pioneering study, extensive research of decisions regarding entry or exit of capitalistic firms in the long run evolved in the literature (e.g., Chavas, Pope and Leathers 1988, Flacco 1983, and Flacco and Larson 1987). The latter authors generalized Sandmo's results, showing that the competitive firm prefers operating (quitting business) when expected profits exceed (fall short of) the risk premium. Later, Finkelshtain and Chalfant (1991) generalized these results to a case in which the producer's preferences are state-dependent.

This section considers the entry and exit decisions of a risk-averse, expected-utility-maximizer cooperative. To date, the entry or exit decisions of a LMF have only been analyzed by Haruna (1988). He showed that if the cooperative is risk averse, then output per member is determined at the point where the expected output price equals marginal cost plus marginal risk premium. Moreover, assuming that in industry with free entry, cooperatives would continue to enter as long the expected utility is positive, he found that

a risk-averse cooperative will produce less output per member than that for which average cost is at minimum.

It is useful to start the analysis in the absence of uncertainty, in which case farmers prefer being members as long as their profit within the cooperative, π , exceeds their riskless profit outside of it, π^o , otherwise the cooperative would be dismantled. Proposition 1 establishes the analogous condition under price risk and demonstrates that the larger the risk or risk aversion, the larger the expected price required for the cooperative to survive in the industry.

Proposition 1: (i) *A positive level of output is produced by the cooperative in the long run if and only if*

$$\mu \geq \frac{C(q) + \phi + \pi^o}{q},$$

where μ is the expected output price, ϕ is the individual member's risk premium.

(ii) *Let μ^* be the level of expected price for which the cooperative members are indifferent as to whether to stay in the cooperative or to dismantle it. Then*

$$\begin{aligned} (i) \quad & \frac{\partial \mu^*}{\partial \rho} \geq 0, \\ (ii) \quad & \frac{\partial \mu^*}{\partial \gamma} \geq 0. \end{aligned}$$

The first part of the proposition states that a necessary and sufficient condition for the cooperative to remain in (quit) the industry is that the expected price exceeds (falls short of) the sum of cost per member, opportunity profit, and the risk premium, all averaged by the output per member. The second part of the proposition states that the expected output-price threshold, for which the cooperative members are indifferent as to staying in business or quitting it, is increases with both the degree of risk aversion and the level of price risk.

Proof: (i) A representative member prefers to keep his membership as long as his expected utility exceeds the utility from the opportunity profit, *i.e.*

$$E[U(\pi)] = U(\bar{\pi} - \phi) \geq U(\pi^o),$$

where $\bar{\pi} \equiv E(\pi)$. Since U is monotonically increasing, the above condition can be rewritten as

$$\bar{\pi} - \phi \geq w \iff \mu \geq \frac{C(q) + \phi + \pi^o}{q};$$

(ii) Note that μ^* is defined by

$$\mu^* \equiv \frac{C(q^*) + \phi(q^*) + \pi^o}{q^*},$$

where q^* is the level of output when the right-hand side is at a minimum. Since ϕ is increasing in both γ and ρ (e.g. Diamond and Stiglitz 1974) for every given level of q , it follows that the right hand side is increasing in these parameters and its minimum is increasing as well thereby completing the proof. ■

Turning to the implications for industry equilibrium, it is again useful to begin with the absence of risk. As with a capitalistic industry, a competitive cooperative industry is at a long-run equilibrium, when the price equals average cost per member, where the latter includes the opportunity profit, π^o , of the members from marketing elsewhere. Proposition 1 facilitates an analogous characterization of the cooperative industry's long-run equilibrium under risk. It implies that, under risk-aversion, long-run equilibrium is characterized by expected dividend above the normal, thus exceeding the opportunity profit.

The second part of the proposition implies that the evolution of cooperative industries involves a natural self-selection: the cooperative members would tend to consist of the less risk averse farmers, while the more risk averse individuals would prefer to market through alternative channels. In addition, an increase in the uncertainty of the economic environment would cause more farmers to prefer a riskless profit over membership in a cooperative.

Additional insight requires the assumptions that all the cooperatives possess identical technologies, and have the same beliefs and risk attitudes. Under these assumptions, the industry is in long-run equilibrium when the level of output per member of each individual cooperative and the equilibrium price distribution both satisfy

$$\mu = \frac{C(q^*)}{q^*} + \frac{\pi^o}{q^*} + \frac{\phi(q^*)}{q^*}.$$

This condition replaces the traditional “price equals average cost per member” or zero economic dividend condition governing the long-run equilibrium of the industry under certainty. Thus, risk and risk aversion drive a wedge between expected price and average cost per member, equal to the member’s average risk premium. This latter condition (or its equivalent in expected utility terms), coupled with the first-order condition, $Q = Q_l l + Q_k k$, create the framework for the comparative statics analysis of the industry to which we now turn.

4. Comparative Statics of Cooperative Industry Under Risk

We shall begin this section with a general framework. In the sequel we will study the effects of various parameter changes on equilibrium variables. Propositions 2-5 are derived under the assumption of a long run planning horizon, where the cooperative enjoys full flexibility in regard to its choice of inputs. At the very end, proposition 6 is derived under the assumption of a short-run horizon, where labor is the only variable input, while capital is fixed (Paroush and Kahana 1980).

To cover the subject fully, the effects of mean preserving spread (MPS) on the output price distribution, which were analyzed by Haruna (1988), are re-derived in Proposition 3. In addition to Haruna’s results we present new findings concerning the effect of MPS on input use as well as the effects of other parameters.

A General Framework

Utilizing the notion of cost per member to model the cooperative behavior, allows us to closely follow the methodology that was introduced by Appelbaum and Katz (1986) for an analysis of a capitalistic industry. The two conditions that characterize the long-run equilibrium of the cooperative industry are

$$a(q, \mu) = E[U_\pi \cdot (p - C_q(q))] = 0,$$

and

$$b(q, \mu) = E[U(\pi) - U(\pi^o)] = 0,$$

where, as before, $p = h(S, \lambda) + \gamma\epsilon$. It is useful to illustrate the conditions $a = 0$ and $b = 0$ with diagrams in the μ and q space. Figures 1 and 2 describe the possible locus of pairs

of μ and q that satisfy either condition $a = 0$ or $b = 0$. Appelbaum and Katz presented analogous figures in the plane of μ and Q . We begin with the slope of each locus.

Totally differentiating the condition $a = 0$ and rearranging terms yields

$$\frac{\partial \mu}{\partial q} \Big|_{a=0} = - \frac{S.O.C.}{E[U_{\pi\pi} \cdot (p - C_q(q)) + EU_{\pi}]},$$

where *S.O.C.* denotes the second-order (sufficient) condition for maximization of expected utility by a single cooperative, which is negative by assumption. Assuming decreasing absolute risk aversion (DARA), Sandmo's technique can be used to show that the denominator is positive, implying that the locus $a = 0$ is positively sloped, as in figure 1. If the absolute risk aversion is increasing, the locus $a = 0$ may (but not necessarily) have a negative slope, as in figure 2.

Totally differentiating the condition $b = 0$ and rearranging terms gives

$$\frac{\partial \mu}{\partial q} \Big|_{b=0} = - \frac{a(q, \mu)}{qEU_{\pi}},$$

Thus, the locus of μ and q satisfying the condition $b = 0$ is a U-shaped curve with a minimum where the first order (necessary) condition $a = 0$ is satisfied.

The equilibrium values of μ and q , denoted by μ^* and q^* , respectively, are achieved at the intersection of the curves $a = 0$ and $b = 0$. The effect of any parameter change on μ is determined only by the shift of the curve $b = 0$, an upward shift implying an increase in μ and a downward shift implying the opposite. The same effect on q , however, is determined by the relative shifts of both $a = 0$ and $b = 0$ along the line $q = q^*$. For example, inspection of figure 1 shows that if $b = 0$ shifts upward more than $a = 0$, then q^* is increased.

Comparative Statics

We start with a demand perturbation, such that the mean price increases while preserving constant variance for every level of the industry supply, S .

Proposition 2: *A spread-preserving increase in demand raises industry output, and the number of cooperatives in the industry. The equilibrium price, output per member, use of inputs and total output per firm remain unchanged. These results are valid, regardless of assumptions about the measures of risk aversion.*

Proof: A spread-preserving increase in demand is modeled by an increase in λ . Such a change only affects μ and leaves the locus that satisfies the condition $a = 0$, or the one that satisfies the condition $b = 0$ as it was, *i.e.* there is movement on the curves rather than of the curves. Hence, the equilibrium levels of expected price and output per member remain the same. Since l and k are functions of only q and r , which do not change, these variables are left unaltered as well, implying that Q , output per firm, also does not vary. Therefore, the spread preserving increase in demand can only be accommodated by a corresponding increase in the number of cooperatives in the industry. ■

The above results concerning the industry equilibrium differ substantially from the results obtained by Paroush and Kahana (1980); Kahana and Paroush (1984); and Choi and Feinerman (1991) who focused on a single LMF. Paroush and Kahana showed that in the short run, when labor is the only variable production factor, DARA implies that the cooperative membership and output levels both decrease with a spread preserving increase in demand. Choi and Feinerman showed that in the long run, when both labor and capital are variable inputs, then, in general, the effects on the firm's output and its use of inputs are indeterminate.

Moreover, the effects of a spread preserving increase in demand on a single capitalistic firm is quite different from its effects on a single cooperative. Specifically, while the capitalistic firm responds to such a spread by increasing its output level (Sandmo 1971), the LMF decreases it (Paroush and Kahana 1980). However, when the industry equilibrium is considered, the qualitative results for both types of firms coincide: a spread preserving increase in demand does not affect output and input choices.

A second type of demand perturbation which is worth studying is a mean-preserving spread (MPS) in the output price distribution.

Proposition 3: *A mean-preserving spread of the price distribution leads to:*

- (i) *an increase in the equilibrium expected price and a decrease in industry supply;*
- (ii) *a reduction in output per member;*
- (iii) *a decrease (increase) in both l and k , if they are positively (negatively) affected by an increase in output price under certainty;*

(iv) a decrease (increase) in the cooperative output and an indeterminate change (decrease) in the number of cooperatives, if output supply under certainty is positively (negatively) sloped.

Proof: (i) Formally, MPS is modeled by an increase in γ . Now, recall that the effect on the equilibrium expected price is solely determined by the shift of the locus $b = 0$ (see figures 1 and 2). Following Sandmo (1971), it can be shown that for every risk averse firm $EU_\pi\epsilon < 0$. Hence,

$$\frac{\partial \mu}{\partial \gamma} \big|_{b=0, q=q^*} = -\frac{E[U_\pi\epsilon]}{EU_\pi} \geq 0$$

implying that, regardless of specific assumptions about the measures of risk aversion, a mean preserving increase in the price variance necessarily increases the equilibrium mean price leading to a reduction in the industry output.

(ii) Now we have to consider the relative shifts of the curves $a = 0$ and $b = 0$ along the line $q = q^*$. The difference between the shifts is given by

$$\begin{aligned} \frac{\partial \mu}{\partial \gamma} \big|_{b=0, q=q^*} - \frac{\partial \mu}{\partial \gamma} \big|_{a=0, q=q^*} &= -\frac{E[U_\pi\epsilon]}{EU_\pi} + \frac{qE[U_{\pi\pi}(p - C_q)\epsilon] + E[U_\pi\epsilon]}{qE[U_{\pi\pi}(p - C_q)] + EU_\pi} \\ &= -q \frac{E[U_\pi\epsilon] \cdot E[U_{\pi\pi}(p - C_q)] - EU_\pi \cdot E[U_{\pi\pi}(p - C_q)\epsilon]}{EU_\pi [qE[U_{\pi\pi}(p - C_q)] + EU_\pi]} \end{aligned}$$

The numerator of the last expression is positive, independent of assumptions regarding the measures of risk aversion (Ishii 1989). If the cooperative exhibits DARA, then the denominator is positive (Sandmo 1971), and the curve $b = 0$ shifts upward less than the curve $a = 0$. In this case q decreases (see figure 1). If the measure of absolute risk aversion is non-decreasing, then the denominator might be negative, implying that the curve $b = 0$ shifts upward more than the curve $a = 0$. However, inspection of figure 2 shows that this case also results in a reduction of q . Therefore, an increase in the price risk reduces the output per member regardless of assumptions on the measures of risk aversion.

(iii) The proof of this part is an immediate consequence of lemma 2.

(iv) By lemma 2, a positively sloped supply curve under certainty implies that a decrease in output per member will decrease the cooperative output. Since both the industry output and the cooperative output decrease the change in the number of firms is indeterminate.

If, however, the supply curve is negatively sloped, the reduction in q leads to an increase in Q . The latter coupled with the reduction in industry output, yield a decrease in the number of cooperatives in the industry. ■

Corollary: If labor is an inferior (normal) input and capital is a normal (inferior) one, then an increase in risk decreases (increases) the cooperative output, increases (decreases) the number of members and decreases (increases) capital use.

The proof of this corollary is immediate when noting that, as shown by Choi and Feinerman, the LMF's supply curve under certainty is positively (negatively) sloped if labor is an inferior (normal) input and capital is a normal (inferior) one.

Our qualitative results regarding the equilibrium values of output price and industry output are identical to those derived by Appelbaum and Katz for a capitalistic industry. Turning to the effect of MPS on the equilibrium output level of a single firm, Ishii (1989) showed that, for a capitalistic industry, an increase in γ decreases Q and ambiguously affects the number of firms even if DARA is assumed. If the cooperative supply curve under certainty is upward sloping, then the same result is obtained with regard to the cooperative output level (proposition 3). However, if the supply curve under certainty is downward sloping (*e.g.* Paroush and Kahana 1980) the result is reversed, namely, MPS increases the LMF's output level. Moreover, in the latter case, proposition 3 also shows that in equilibrium the number of LMFs, n , decreases.

It can be inferred from Paroush and Kahana's analysis for a single LMF in the short run, that DARA implies a reduction in equilibrium output in response to MPS. Extending the analysis of a single LMF into the long run, Choi and Feinerman (1991) have found that the effect of MPS on the LMF's output level is ambiguous. The current study further extends the analysis by considering the long-run industry equilibrium and obtains unambiguous results with regard to the effect of MPS on Q depending on the slope of the cooperative supply curve under certainty.

We turn now to an analysis of marginal variation in the risk attitudes of the industry participants. This question was never fully addressed in previous studies of LMFs under price risk. However a partial study of the subject is provided by Choi and Feinerman (1991) who compared risk-neutral and risk-averse LMFs. Since in real life various degrees

of risk aversion are observed rather than only risk neutrality or risk aversion, a marginal analysis is of interest.

Proposition 4: *An increase in risk aversion leads to:*

- (i) *an increase in the equilibrium expected price and as a result, a decrease in industry supply;*
- (ii) *indeterminate changes in output per member, input levels, cooperative output and number of cooperatives in the industry.*

Proof: (i) An increase in risk aversion is modeled by an increase in γ . Totally differentiating the condition $b = 0$ with respect to μ and ρ , yields

$$\frac{\partial \mu}{\partial \rho} \Big|_{b=0, q=q^*} = - \frac{EU_\rho(\pi) - U_\rho(\pi^o)}{qEU_\pi}.$$

Thus the sign of the above derivative is opposite that of $EU_\rho(\pi) - U_\rho(\pi^o)$. But

$$E[U_\rho(\pi) - U_\rho(\pi^o)] = \int U_\rho[dF^1(\pi) - dF^2(\pi)],$$

where $F^1(\pi)$ is the probability distribution function of π induced by the distribution of p , and $F^2(\pi)$ is the degenerate distribution of w . Integrating the right-hand side of the last equation by parts twice yields

$$\begin{aligned} - \int U_{\rho\pi}[F^1(\pi) - F^2(\pi)]d\pi &= - \int \frac{U_{\rho\pi}}{U_\pi} U_\pi[F^1(\pi) - F^2(\pi)]d\pi \\ &= \int \frac{\partial^2 \log U_\pi}{\partial \pi \partial \rho} \int^\pi U_\pi(\theta)[F^1(\theta) - F^2(\theta)]d\theta d\pi, \end{aligned}$$

where θ is an integration variable. The first term, $\frac{\partial^2 \log U_\pi}{\partial \pi \partial \rho}$, is negative by the definition of ρ . Since the distribution F^2 is less risky, the second term, $\int^\pi U_\pi(\theta)[F^1(\theta) - F^2(\theta)]d\theta$, is positive (Diamond and Stiglitz 1974). Thus

$$\frac{\partial \mu}{\partial \rho} \Big|_{b=0, q=q^*} \geq 0.$$

(ii) The effect of an increase in risk aversion on q^* depends on the relative shifts of the curves $a = 0$, $b = 0$ along the line $q = q^*$. Unfortunately, the difference

$$\frac{\partial \mu}{\partial \rho} \Big|_{b=0, q=q^*} - \frac{\partial \mu}{\partial \rho} \Big|_{a=0, q=q^*}$$

cannot be signed, therefore the effect on q^* is indeterminate. Since l , k , Q and n are all determined by the level of q^* the effects of an increase in ρ on these variables are also indeterminate. $\square$

It is somewhat surprising that while the effect of an increase in price risk can be inferred once the slope of the supply curve under certainty is known, the effect of an increase in risk aversion is ambiguous. These results are consistent with those of Choi and Feinerman (1991) who compared the behavior of risk neutral and risk averse LMFs and found that the impact of risk aversion is, in general, ambiguous.³

The long-run viability of cooperative firm depends on the alternative profit available to the members through other marketing channels. It is therefore important to examine the effect of this reservation profit on the equilibrium of the cooperative industry. This issue is investigated in proposition 5.

Proposition 5: *An increase in the reservation profit, w , leads to:*

- (i) an increase in the equilibrium expected price and a decrease in industry supply; and assuming DARA,*
- (ii) a rise in output per member;*
- (iii) a decrease (increase) in both l and k , if they both decrease (increase) in output price under certainty;*
- (iv) an increase (decrease) in the cooperative output and a decrease (indeterminate change) in the number of cooperatives, if the cooperative output supply is positively (negatively) sloped*

Proof: (i) Totally differentiating the condition $b = 0$ and rearranging gives

$$\frac{\partial \mu}{\partial w} \Big|_{b=0, q=q^*} = \frac{U_{\pi}(\pi^o)}{qEU_{\pi}(\pi)} \geq 0.$$

Thus, regardless of any specific assumption about the measures of risk aversion, an increase in the reservation profit must increase the mean price, resulting in a reduction of industry output.

³ It is worth mentioning, however, that Choi and Feinerman have shown that if labor and capital are substitutes and labor is inferior, then a risk averse LMF produces more than a risk neutral LMF.

(ii), (iii), (iv) Since a change in the reservation profit does not affect the condition $a = 0$, the increase in expected price implies an increase in output per member if the condition $a = 0$ is upward sloping. The latter is ensured by DARA. The proof is completed by considering the effects of a change in output per member on l , k and Q established by lemma 2 above. ■

Corollary: If labor is an inferior (normal) input and capital is a normal (inferior) one, then an increase in reservation profit increases (decreases) the cooperative output, decreases (increases) the number of members and increases (decreases) capital use. The proof is similar to that of the corollary following proposition 3, and is available upon request.

The results regarding the equilibrium values of expected price and industry output, are similar to those derived by Appelbaum and Katz (1986). If inferior labor and normal capital are assumed, our findings with regard to output per firm also coincide with their result, which does not depend on factor characteristics. However, assuming inferior capital and normal labor, the result derived here, with regard to firm output, is opposite to the one derived by Appelbaum and Katz.

The analysis conducted so far presumed that all inputs can be optimally chosen by the cooperative, namely a long-run planning horizon was assumed. Finally and in order to draw comparisons with previous studies, we now assume that capital is fixed and perform a comparative statics analysis with respect to fixed cost, T .

Proposition 6: *Regardless of any specific assumption about the measures of risk aversion, an increase in fixed cost, leads to:*

- (i) *a rise in expected price and a reduction in total industry output;*
- (ii) *a decrease in output per member and an increase in the number of members;*
- (iii) *an increase of the cooperative output supply and a decrease in the equilibrium number of cooperatives.*

Proof: (i) The effect of an increase in fixed cost on the expected price is found through the condition $b = 0$, evaluated at a predetermined level of k

$$\frac{\partial \mu}{\partial T} \Big|_{b=0, q=q^*} = \frac{EU_{\pi} C_T}{q EU_{\pi}} = \frac{C_T}{q} \geq 0.$$

Thus, an increase in the reservation profit must increase the mean price and reduce industry output.

(ii) To further explore this case, we have to consider the relative shifts of the curves $a = 0$ and $b = 0$ along the line $q = q^*$ for a fixed k . The difference between the shifts is given by

$$\begin{aligned} \frac{\partial \mu}{\partial T}|_{b=0, q=q^*} - \frac{\partial \mu}{\partial T}|_{a=0, q=q^*} &= \frac{C_T}{q} - \frac{E[U_{\pi\pi}(p - C_q)]C_T + EU_{\pi}C_{Tq}}{qE[U_{\pi\pi}(p - C_q)] + EU_{\pi}} \\ &= \frac{EU_{\pi}C_T - qEU_{\pi}C_{Tq}}{q[qE[U_{\pi\pi}(p - C_q)] + EU_{\pi}]} \end{aligned}$$

The sign of the numerator is the same as $\text{sgn}(C_T - C_{Tq})$. In this case $C = \frac{T}{l(q)}$, giving

$$\text{sgn}(C_T - C_{Tq}) = \text{sgn}\left(\frac{1}{l} + \frac{q}{l^2} \frac{\partial l}{\partial q}\right).$$

Substituting $(\frac{\partial Q}{\partial q} - l)\frac{1}{q}$ for $\frac{\partial l}{\partial q}$ shows that

$$\text{sgn}(C_T - C_{Tq}) = \text{sgn}\left(\frac{\partial Q}{\partial q}\right),$$

which is clearly negative in this case. Hence, the numerator is negative, regardless of the assumption on the measures of risk aversion. If the denominator is positive (absolute risk aversion is decreasing), then the curve $b = 0$ shifts upward less than the curve $a = 0$ and, as implied by figure 1, q decreases. If the denominator is negative, the curve $b = 0$ shifts upward more than $a = 0$. However, as implied by figure 2, q also decreases. Thus, an increase in fixed costs reduces the output per member, regardless of assumptions on the measures of risk aversion. The increase in number of members, $\frac{\partial l}{\partial T} > 0$, follows since in this case $\frac{\partial l}{\partial q}$ is negative.

(iii) There are two ways of seeing why the cooperative output increases: first, it is implied by the increase in l ; second, in this case, Q moves in the opposite direction to q (Paroush and Kahana). It follows immediately that the number of cooperatives decreases. $\square$

These results are the same as those derived by Appelbaum and Katz (except the one with regard to l which is not discussed by them). This similarity is not trivial, however, since in the current case the fixed cost per member decreases with the number of employees. It is also worth noting that without the industry equilibrium condition, the capitalistic firm would reduce its output as the fixed costs rise (Sandmo) while the cooperative would increase it (Paroush and Kahana).

Concluding Remarks

A recent theme in the economic literature is a rigorous study of alternative organization forms of firms and markets and their implication regarding industry performances. The current paper contributes to this evolving literature by extending the theory of LMFs behavior under uncertainty. Specifically, we focus on the entry and exit decisions of a single cooperative and the competitive long-run equilibrium of cooperative industry. The extended framework may be utilized by policy makers to better understand the possible impact of changes in various exogenous (behavioral, environmental, industrial, and technological) parameters on a single cooperative decisions and the industry equilibrium characteristics.

There are several directions into which the current analysis can be profitably extended. First, the assumption of homogeneous cooperatives can be relaxed and the analysis may proceed with either inter or intra firm differences, *e.g.* in technology, expectations, risk attitudes, or reservation profit due to heterogeneity in skills. Second, since many cooperatives face technological risk, it is important to extend the framework to accommodate this additional risk source. Third, a real challenge for future research is a formulation of an equilibrium model allowing co-existence of both capitalistic firms and cooperatives. Such a study may facilitate the investigation of three important issues: i) conditions under which both types of firms can (or cannot) co-exist; ii) the effects of the share of each organization form on the industry performances; and iii) the effects of exogenous parameters, such as governmental policies, on the long run industry share of each organization type.

Appendix

Proof of the Equivalence between the Direct and the Two- Stage Maximizations

The expected utility maximization with respect to the two inputs and the first of the two-stage maximization are expressed formally as:

$$(A) \quad \max_{l,k} EU \left(\frac{pf(k,l)}{l} - \frac{rk}{l} \right) \quad \text{and}$$

$$(B) \quad \min_{l,k} \frac{rk}{l} \quad \text{subject to :} \quad \frac{f(k,l)}{l} \geq q,$$

respectively. The first-order-conditions for (B) are

$$k : \quad \frac{r}{l} = \lambda \frac{f_k}{l}$$

$$l : \quad -\frac{rk}{l^2} = \lambda \frac{f_l l - f}{l^2}$$

Multiplying the conditions by kl and $-l^2$, respectively, equating the two right-hand sides, and dividing by λ gives: $f_k k + f_l l = f$. The first-order-conditions for (A) are (see Choi and Feinerman (1991))

$$k : \quad \frac{1}{l} E\{U' \cdot pf_k\} = \frac{1}{l} E\{U' \cdot r\}$$

$$l : \quad \frac{1}{l} E\{U' \cdot p(f_l - f/l)\} = -\frac{1}{l} E\{U' \cdot rk/l\}$$

Multiplying the conditions by kl and $-l^2$, respectively, equating the two left-hand sides, and dividing by $E\{U' \cdot p\}$ gives: $f_k k + f_l l = f$. Thus, if a choice of l and k solves the maximization in (A), it also solves the minimization in (B).

Corollary: problem (A) is equivalent to $\max_q E(pq - c(q))$ where $c(q)$ is the minimum cost per worker function defined as (B). ■

Outline of the Proof of Lemma 2

The proofs of parts (i) and (ii) of lemma 2 are immediate when comparing the consequences of comparative statics results from the following two systems.

1. Total differentiation of the first-order conditions resulting from profit maximization

$$pQ_k - r = 0$$

and

$$pQ_l l - pQ + rk = 0$$

with respect to l , k and p .

2. Total differentiation of the local CRS condition resulting from expected utility maximization and the definition of output per member

$$Q_l + Q_k \frac{k}{l} - q = 0$$

and

$$\frac{Q}{l} - q = 0$$

with respect to l , k and q .

The proof of part (iii) of Lemma 2 follows by differentiating the production function with respect to p :

$$\frac{dQ}{dp} = Q_l \frac{\partial l}{\partial p} + Q_k \frac{\partial k}{\partial p},$$

with respect to q :

$$\frac{dQ}{dq} = Q_l \frac{\partial l}{\partial q} + Q_k \frac{\partial k}{\partial q},$$

and using parts (i) and (ii) of Lemma 2. ■

Figure 1: Equilibrium with Positively Sloped Supply

Figure 2: Equilibrium with Negatively Sloped Supply

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CHAPTER 4: PRICES VS. QUOTAS IN AN ORGANIZATION

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I. Introduction

The management of marketing organization must regulate the quantity and quality of the products, supplied by the organization members. The regulation regime may involve quantity measures, such as quotas and standards or incentives in the form of prices and quality premia. The management of marketing organization is usually subject to pressure from member farmers in order to bend the policy in their favour. For example, dairy farmers from various sectors in Israel are lobbying to increase their milk quotas. The purpose of this chapter is to examine whether price regulation is superior to quantity regime or vice versa. The analysis is proceeded with a government that regulate a negative externality. The results, however, are general and are applicable to a variety of organizational forms and regulation problems.

We ask the following question: given that government intervention is subject to lobbying and political pressure, when is regulation by prices the preferred regime and when is a quantitative control more adequate? The neoclassical answer to the control dilemma is that price and quota regimes are identical in their effect—both yield the same resource allocation and social welfare level. But, as Martin Weitzman (1974) has already shown, the equivalence of the controls does not hold where information is imperfect and monitoring incomplete.¹ We focus on a different issue, on the political aspect.

The analysis is of a single regulated industry, employing a factor with negative or positive external effects. The political equilibria, and hence the magnitudes of the distortions, differ with the external effect and the implemented control. Under quota and when taxes are imposed to reduce negative effects, the use of the controlled factor will be between the

¹ For extensions and applications of Weitzman's analysis, see, for example, Fisher (1981) and Cropper and Oates (1992).

privately profit maximizing utilization and the social optimum; with subsidies (when the effects are positive) the political struggle is for higher payments and equilibrium allocation will be higher than both private, non-intervention, utilization and the social optimum. In this case, resource allocation in the political equilibrium may be worse than the free market factor utilization.

It is further shown—for negative externalities—that the comparative advantage of either of the control regimes depends on a factor involving the share of organized producers in the industry, the value of the demand elasticity for the regulated good, and the tax rate. A price regime yields a more efficient political equilibrium when this factor is smaller than 1. When not, quota is the more efficient instrument. The preferred control cannot be unambiguously characterized when the external effects are positive. Finally, describing the political process as a menu auction with a single industrial lobby, we show that the relatively more efficient regime in terms of resource allocation induces a lower level of rent-seeking expenditures.

II. Society and Polity

Regulation is called for where external effects exist—in production or consumption, where scale economies lead to natural monopoly, or in the provision of public goods. The analysis in the paper is confined to regulation of a factor of production with externalities affecting consumers or producers elsewhere in the economy; they do not affect producers in the regulated industry. As an example of a negative externality consider an irrigation project lowering water table of a nearby urban center. For an example of a positive effect, take the utilization and disposition of reclaimed sewage. Restricting the discussion to an input does not affect the generality of the conclusions.

The producers using the regulated factor are assumed to behave rationally and disregard externalities associated with their activity. In a free market, the producers tend to overutilize factors of production with negative effects and underuse factors with positive effects. A social planner, taking into account both the value of production in the controlled

industry and its effect on others, can determine socially optimal utilization of the factor. (Income distribution is disregarded in the analysis.)

The government in our analysis is a political entity whose own utility is affected both by social welfare and by political rewards or contributions. The producers and the government (the politicians), being engaged in a political give and take, constitute a *polity* and the ensuing allocation reflects the equilibrium reached in the political struggle. The government willingly accepts rewards and bends its policy, but it is not powerless. We assume that if a political agreement is not achieved, socially optimal resource allocation is enforced. The producers may also retreat to the social allocation and thus deprive the politicians of the rewards they desire. The social optimum is the threat point of the political game.

The producers operate in the political arena individually or they are organized in lobbies. We analyze the effect of collaboration in the influence groups, but do not discuss the structure of the lobbies and modes of collaboration. Also, by our assumption, the individual political contribution is not determined in the political equilibrium; it is left to the lobby to charge its members. Political rewards may come in all shapes and forms: monetary political contributions (or even outright bribes), demonstrations, letter writing, and assistance in campaigns. They may be negative when the producers punish the government or demonstrate against it. Sometimes the political rewards may enhance welfare—the welfare of the receiving politicians or welfare in a wider sense as when a builder offers a new school in return for a desired permit.

The discussion in the paper is limited to the effect of political contributions on government regulation; the nature of the rewards and their wider implications are not analyzed. As in Grossman and Helpman (1994), only “linear”, money-like rewards are considered, restricting the political influence technology to exhibit constant return to scale. This assumption simplifies the analysis considerably by permitting recursive calculation of the variable making the political equilibrium: the use of the controlled factor is set in the

first stage; the political rewards—the distribution of the surplus—are determined in the second stage. An important advantage of the “linear-model” is that factor allocation is the same for a variety of political economies. The political contributions, on the other hand, are model-specific. We remark on possible generalizations in the concluding section of the paper.

The political process we consider is embedded in a “constitution” by which the control regime may be either a quota or a price regime. The constitution is accepted as predetermined, it is not debatable and we do not consider here the political process leading to its establishment.²

Our main concern is with comparing a quota with a price regime. Under quota the producers must comply with administrative regulations, with a price control they either pay a tax or receive a subsidy and choose freely the quantity of the factor they use. Focusing on the efficiency of the controls, we eliminate income differences by introducing revenue-neutral policy shifts; that is, lump-sum payments are seen as balancing taxes or subsidies. For example, when the shift is from a quota to a tax, the government pays up front the value of the taxes which will be applied in the political equilibrium. A shift to a subsidy regime entail a compensating lump-sum tax. Similarly, a shift from a tax to a quota control is associated with a lump-sum payment to the government. The compensation is not debatable and the producers cannot expect to affect it even if the magnitude of the tax or the subsidy is modified in the political negotiations which proceed once the control regime has been in place and the compensation scheme implemented.³

² A similar approach is taken by both Rodrik (1986) and Grossman and Helpman (1994) who view the evolution of the political process as proceeding in two stages. In an analysis of the political choice of regimes, Buchanan and Tullock (1975) concluded that politicians will, generally, prefer quantitative controls. They ignore, however, the possibility that rent seeking activities will modify the levels of control once they are implemented.

³ Lump-sum compensating payments eliminate income effects of control regimes and

Compensations of this nature are observed in reality. The government of Israel, for example, is "purchasing" these days production quotas in agriculture in an attempt to gain political acceptance of steps toward elimination of planning and administrative intervention in farming.

III. Recent Theories of Political Economy

Political processes affecting public intervention in the economy have been the subject of intensive literature. Examples are: Zusman (1977) in the fields of agricultural marketing and natural resources, Rodrik (1986), Hillman (1989) and Grossman and Helpman (1994) in the context of international trade, and Scarpa (1994) who studies the consequences of political influence by a public utility. These studies analyze political equilibria for particular control regimes. In contrast, we attempt to compare the performance of alternative politically influenced regimes.

The political process may be viewed in many ways. Following the Peltzman (1976) tradition, the government is seen in Hillman (1989) as setting policies to maximize a political support function which trades welfare of voters with divergent interests. In Zusman (1976) and in Scarpa (1994) the political process is a Nash (1950) bargaining game with politicians and lobbies negotiating policy parameters and political contributions. Grossman and Helpman (1994) formulize the political process as a menu auction.

The models differ, but they share a common property: the equilibrium reached is politically efficient, it is located on the polity's contract curve. Moreover, as we show shortly, with linear political rewards, the allocation of the controlled factor is independent of the magnitude of the political contributions and all the above models predict identical allocations (Hillman does not specify rewards explicitly). We are making use of this property in the next four sections of the paper.

facilitate an analysis of net allocation effects. Sometimes, however, a crucial consideration in the choice of a control is revenue raising and cost covering. These considerations are disregarded in the present analysis.

IV. The Model

Net income of a producer in the regulated industry is

$$y^i = \pi^i(q^i) - c^i - tq^i + R^i, \quad (1)$$

where q^i marks the i th producer's utilization level of the regulated factor and the magnitude t marks the tax imposed by the government (for a subsidy $t < 0$). The compensation payment is R and it is equal to the equilibrium level of tq . The variable c^i indicates political contributions. The function $\pi^i(q^i)$ is the i th producer's profit in the production activity, it is concave and it subsumes the prices of goods other than the regulated good. It also subsumes the private market price, p , of the regulated factor but taxes or subsidies are not included in π . The industry supplying q is competitive and characterized by constant return to scale with perfectly elastic supply. There are N producers in the regulated industry and total factor utilization and political rewards are given, respectively, by

$$Q = \sum_{i=1}^N q^i \quad \text{and} \quad C = \sum_{i=1}^N c^i. \quad (2)$$

If only K producers participate in the industry's lobby ($K < N$), c^i may be zero for some values of i .

The second sector, the government, is viewed as maximizing the weighted sum

$$W = V(\mathbf{q}) + \alpha C, \quad (3)$$

where $V(\mathbf{q})$ is social welfare defined over the vector $\mathbf{q} = q^1, \dots, q^N$ and the constant $\alpha > 0$ represents the preference of the government for political bribes relative to public welfare. It can also be seen as standing for the political power of the influence group in the industry. Lobbies in different industries may have different α values.

The welfare function, V , is given by

$$V(\mathbf{q}) = \sum_{i=1}^N \pi^i(q^i) + \sum_{j=1}^M \mu^j(Q), \quad (4)$$

where $\mu^j(Q)$ is the money-metric utility function of the j th person who is affected by the external effects of the regulated factor. The function μ increases with Q for positive externalities and decreases for negative effects. Utility is also defined over the vector of prices of consumption goods; but, assuming a small economy with all goods traded, prices are constant and they are not represented explicitly in the function.

It is assumed that μ^j is concave in Q , and hence in each q^i . Similarly, since V is the sum of concave functions (in each q^i), it is a concave function itself. All functions are second order differentiable and interior solutions are assumed throughout.⁴ It is also assumed that enforcement of the regulation instrument is costless.

Due to externalities, optimal levels of q^i from the points of view of the producer, q_i^{pr} , and the society, q_i^s , do not agree. That is,

$$q_i^{pr} = \arg \max_{q_i} [\pi(q)] \neq q_i^s = \arg \max_{q_i} [V(q)]. \quad (5)$$

This, of-course, creates the conflict that induces rent seeking and political rewards.

As indicated, producers in an industry may operate in the political arena individually or in the industrial lobby. We assume that a lobby maximizes total income of the members in the group

$$Y = \sum_{k=1}^K y^k \quad (6)$$

The formulation is general: an industry may have just a single producer ($N=K=1$), this may be a monopsonist in the use of the regulated factor, perhaps a public utility. Alternatively, some or all producers in an industry may form an influence group and lobby for their interests.⁵

⁴ Among other things, interior solutions mean that all producers use positive quantities of q at any of the prices considered.

⁵ With linear political rewards, the analysis is not modified by the number of lobby groups in the industry. For simplicity and brevity, the discussion is conducted in terms of a single lobby.

One difference between the regimes affects behavior in a crucial way: Taxes are uniform and, in an industry with many producers, both those who lobby to modify the policy and the producers who do not—face the same tax. We show that an industry with a comparatively large share of free riders is politically weaker but, as indicated, we do not analyze the internal structure of the lobby groups and the forces that keep them together.

Under a quantity control, on the other hand, a producer who does not engage in political activity, will be assigned the social quota (with negative externalities non-participants may even get zero quotas to balance overutilization by the political activists). There is therefore no free riding in the political equilibrium of a quota regime, all producers participate and are members of the industrial lobby.⁶

V. Equilibrium Utilization of the Regulated Factor

In the first stage of the recursive calculation of the political equilibrium we set the allocation of the regulated factor. This first stage is described here. The determination of the contributions by the K politically active producers is done in the second stage which is presented in Section VII.

Let γ mark a common label for the allocation parameters in the two alternative regimes considered in the paper: a quota system where $\gamma = \mathbf{q} = q^1, \dots, q^N$; and indirect control, a price regime with a per unit tax or subsidy, $\gamma = t$. Exogenous to the political equilibrium are: the production technology, prices, private and social preferences and the constitution specifying the instrument of regulation.

An efficient agreement between the government and the producers, located on the polity's contract curve, can be characterized by the necessary conditions for an internal solution to the following constrained maximization problem:

$$\gamma^*, \mathbf{c}^* = \arg \max_{\gamma, \mathbf{c}} W(\gamma, \mathbf{c}) \quad \text{S.T.} \quad Y(\gamma, \mathbf{c}) \geq \bar{Y} \quad (7)$$

⁶ Similar considerations underlie Rodrik's (1986) analysis of trade with either a uniform tariff or firm specific subsidies.

In eq. (7), $\bar{Y}$, defined as in (6), is the reservation utility, the alternative income of the lobby members in the event that an agreement is not reached and c is the vector of political rewards. We commence with a quota control.

A. A Quota Control

The government sets quotas, q , the magnitudes of which are subject to political pressure. In this case $y^i = \pi^i(q^i) - c^i$ and a politically efficient agreement concerning q satisfies (7) and is characterized by the following N first order conditions (derivatives are marked as subscripts):

$$\pi_q^i(1 + \alpha) = - \sum_{j=1}^M \mu_Q^j(Q) \quad i \in \{1, \dots, N\}, \quad (8)$$

Remarks: a. The political rewards, c^i , do not appear in the necessary conditions for the determination of the quotas. This verifies our earlier assertion on the recursive nature of the solution of the political equilibrium. b. The utilization of the regulated factor does likewise not depend on the compensation, R . c. Equations (8) will be the same whether the producers in the industry are unionized in a single lobby, in several groups, or they operate individually; political organization does not affect the equilibrium reached. These three features are due to the linear nature of the political reward system, the equilibrium would have been different with nonlinear rewards—if the political action was subject to economies or diseconomies of scale.

A useful result that emerges from condition (8) is that, as the right-hand-side, $\sum_{j=1}^M \mu_Q^j(Q)$, is identical for all i , $\pi_q^i = \pi_q^j = \pi_q \quad \forall i, j \in \{1, \dots, N\}$ (similarly, $V_{q^i} = V_{q^j} = V_q \quad \forall i, j \in \{1, \dots, N\}$). In words, the value of the marginal profit (VMP) of the regulated factor is the same for all producers. The political game distorts the level of aggregate factor utilization, but allocation among producers is efficient. This is a reflection of producers with higher VMP pressing harder for quotas⁷. When resources are admin-

⁷ The argument that producers with higher VMP press harder relies on a "truthful" property; namely, that producers struggle more—offer higher rewards—for more valuable political favors. We comment further on this property in Section VII.

istratively allocated, the political process replaces the market in securing between-firm efficiency.

Because of the signs of the derivatives μ_Q^j , equation (8) implies that for negative (positive) externalities $\pi_q^i > (<)0$. In addition, equations (8) can now be rewritten as

$$V_q = -\alpha\pi_q, \quad (8')$$

which implies that for negative (positive) externalities $V_{q^i} < (>)0 \forall i \in \{1, \dots, N\}$. Since all VMP's are equal, all the q^i values move together, and it follows unambiguously from the sign of V_q that for negative (positive) externalities $q_i^{po} > (<)q_i^s \forall i \in \{1, \dots, N\}$. Thus, under quota, the political equilibrium is a "compromise": When externalities are negative, factor utilization exceeds the social optimum (where $V_q = 0$) but is lower than free market use (characterized by $\pi_q = 0$). With positive externalities, utilization at the political equilibrium is smaller than socially optimal and larger than the private profit maximizing quantity. These findings are summarized in the first two lines of Table 1.

Table 1: Properties of the Political Equilibrium

	<u>Marginal contribution of q</u>		<u>Quantity</u>
	<u>Social</u>	<u>Private</u>	
Negative Externalities			
Quota/Tax	$V_q < 0$	$\pi_q > 0$	$Q^s < Q^{po} < Q^{pr}$
Positive Externalities			
Quota	$V_q > 0$	$\pi_q < 0$	$Q^{pr} < Q^{po} < Q^s$
Subsidy	$V_q < 0$	$\pi_q < 0$	$Q^{pr} < Q^s < Q^{po}$

The political equilibrium is depicted graphically for a single producer and negative externalities in Figure 1.

*** Figure 1 about here ****

The graphs W_1, W_2 and y_1, y_2 , are the government's and the producer's indifference curves; their slopes are $-V_q/\alpha$ and π_q^i , respectively. (For the government, the curve is drawn with all other producers at the equilibrium configuration.) Because of differences in political payments, $W_2 > W_1$ and $y_2 > y_1$. Each indifference curve of the government has a minimum at $q = q^s$, the socially desired level, and the point $q = q^s, c = 0$ is the disagreement threat point. The equilibrium quota is q^{po} and the segment $[a, b]$, between indifference curves passing through the origin, marks the core of the political game.

B. Indirect Control

A pure price control is either a tax or a subsidy. In this case $y^i = \pi^i(q^i) - tq^i - c^i$ (R omitted), and the producer is free to utilize any quantity of the factor. The private first order condition characterizing the producer's choice of q^i is then

$$\pi_q^i = t, \quad (9)$$

which implies

$$\frac{\partial q^i}{\partial t} = \frac{1}{\pi_{qq}^i}. \quad (9')$$

By (9), $q^{po} < (>) q^{pr}$ for negative (positive) effects.

Solving (7) with respect to t and c , while using equation (9), yields the condition that characterizes the political equilibrium under a price regime:

$$\sum_{i=1}^N V_{q^i} \frac{\partial q^i}{\partial t} = \alpha Q^K, \quad (10)$$

where Q^K is the aggregate factor utilization by the members of the industrial lobby. The marginal effect of a tax on the whole industry is balanced against its effect on the active group whose utility is reserved on the political contract curve. The remarks following eq. (8) on the independence of allocation apply here too. Also, producers in an industry controlled by prices may operate in several groups, their contributions will be aggregated by the receiving politicians in the government and their effect will be a function of the sum. In this situation, K stands for the total number of participants in all groups.

From $\pi_q^i = t \ \forall i \in 1, \dots, N$, it follows that $V_{q^i} = \pi_q^i + \sum_{j=1}^n \mu_Q^j = V_q \ \forall i \in \{1, \dots, N\}$ and that (10) can be written as

$$V_q = \alpha Q^K \frac{\partial t}{\partial Q}. \quad (11)$$

By concavity of π^i , $\pi_{qq}^i < 0$, and then by (9'), $\partial t / \partial Q < 0$, implying that $V_q < 0$ regardless of the sign of π_q . Thus, under a price control the producers over-utilize (socially) the regulated factor, both when the external effects are negative and when they are positive. With negative externalities, the political pressure is to reduce the tax; with positive effects, it is to increase the subsidy—up to and above the social optimum. Consequently, while under a quota regime the political equilibrium is always a compromise (between the free market allocation and the social optimum), a price regime may yield, in the presence of political power and when the external effects are positive, an allocation that is *socially worse than the free market utilization of the regulated factor*. In the presence of political pressure, the intervention of an otherwise benevolent government may worsen resource allocation.

That taxes and subsidies differ in their effects on resource allocation modifies—for a political economy—the Coase (1960) and Weitzman (1974) conclusion that property rights do not affect the nature of the solution to an externality problem. If the producer owns the right to pollute the air, to take an example from these references, q will stand for the resources going into pollution prevention, their use will have positive externalities and will be subsidized. If the public, represented by the government, owns these rights—the polluters will be taxed. With political pressure, resource allocations will differ: in the first case the equilibrium will be characterized by overinvestment in pollution prevention, it will be sub-optimal in the second.

Another useful way to write eq. (11) is

$$V_q = \alpha \frac{\sigma}{s\eta} \pi_q, \quad (12)$$

where $s = t / (p + t)$, η is the factor demand elasticity, defined at the price the producer actually pays, $p + t$, and $\sigma = Q^K / Q$ is the share of the regulated factor utilized by the

producers in the lobby group.⁸ The formulation of (12) is utilized in the analysis to follow. Expressing V_q in its extended form, eq. (12) can be rewritten as

$$\sum_{j=1}^M \mu_Q^j = \pi_q \left(\frac{\alpha\sigma}{s\eta} - 1 \right), \quad (13)$$

which implies that, for positive externalities and a price regime, internal, tangency solutions are confined to the region where $\alpha\sigma/s\eta < 1$.

VI. Comparative Efficiency of Factor Allocation

We are ready now to turn to the question of *prices or quantities*. To examine it, we define: a control yields a *more efficient utilization* of the regulated factor than the alternative regime if and only if it yields a higher level of social welfare, $V(q)$.

A. A Formal Proposition

With negative externalities, both under quota and in a tax regime, the quantity of the regulated factor is between the privately desired level and the social optimum. This “closeness” of the equilibria enables an analysis of the comparative performance of the alternative regimes. Such an analysis is impossible for a positive externality because of the distance between equilibria in which, under a quota, q is lower than the social optimum and with a subsidy—it is above the optimum. These considerations are reflected in the following proposition which summarizes the principal findings of the paper.

Proposition 1: *Suppose that the government is regulating the utilization of a factor by either a price or quota control. The factor is used by many producers. With quotas all producers are represented in the political process; with prices, not all producer are necessarily members of the industrial lobby. Consider a political equilibrium calculated for a price regime, either a tax or a quota, then,*

⁸ With a subsidy ($t < 0$), s can be either negative or positive. When $|t| < p$, $s < 0$; when $|t| > p$, $s > 0$. In the latter case, calculated $\eta > 0$; in both cases, $s\eta > 0$. For completion, we set $s\eta = 1$ for $|t| = p$.

- (i) *with a negative externality, a price (quota) regime yields a more efficient factor utilization, if and only if $|\sigma/\eta s| < (>)1$;*
- (ii) *with a positive externality, a price regime yields a larger factor utilization than under quota, efficiency comparison is however inconclusive;*
- (iii) *under both types of externalities, the efficiency of a price relative to a quota control increases with the elasticity of the demand for the regulated factor and decreases with the share of organized producers in total production;*
- (iv) *efficiency of both controls increases with the ethical norms of the politicians, $1/\alpha$.*

Proof : Part (i). Mark $\epsilon = |\sigma/s\eta|$. For $\epsilon = 1$, resource allocation under quota is identical to allocation in a tax regime. To compare the controls, consider a shift in a given industry from a quota to a tax. Since the move is between equilibria, the compensation (R) is implemented and the only difference in the first order condition is in the value of ϵ . Examining (8') and (12) one realizes that for $\epsilon < 1$, V_q in (12) is smaller in absolute value than in (8'); a tax regime is then comparatively more efficient. The inequality is reversed for $\epsilon > 1$, as required for the proof. Part (ii) is proved by noting that because of the differences in V_q values in Table 1, comparative advantage cannot be determined. Part (iii) and (iv) are proved by examination of (12). □

We turn now to interpretations and elaborations.

B. Demand Elasticity

The intuition behind the role played by demand elasticity in comparing efficiency of the regimes in Part (i) of Proposition 1 can be explained conveniently for $\sigma = 1$, $p = 0$, $s = 1$; that is, the industry consists of a single producer or of an all embracing lobby, there is no charge for the factor q under a quota regime, and the tax is the entire unit price under a price regime. For this situation, q_0 in Figure 2 is an initial quantity, either determined by a quota or reached by the producer when the tax was set to t_0 .

*** Figure 2 about here ***

Consider the rent seeking effort that increases the quantity to q_1 . Depending on the control, the change may be achieved by either an increase in the quota itself or by reducing the tax to t_1 . The corresponding gain to the producer is

Price regime $A + B$

Quota regime $B + C$

Difference $A - C$.

With unitary elasticity, $A = C$ and the difference vanishes, the regimes are equivalent at the margin. The returns to marginal political efforts of equal quantitative effects are identical. Alternatively, if the factor demand is elastic, $A < C$, the returns under a price regime are smaller than under quota. Consequently, under a price regime the political struggle is less intensive, and the equilibrium is closer to the social optimum. Similarly, for Part (iii), the more elastic the demand function passing through (q_0, t_0) the smaller the area $A + B$, and the less intensive the political struggle. In Figure 1, more elastic demand is expressed in smaller slopes of the producer's indifference curves and a move of the political equilibrium quantity to the left.

These findings may seem to contradict the established Ramsey- Boiteux tradition (Atkinson and Stiglitz, 1980) of optimal taxation by which the more elastic the demand (or supply) the more socially harmful an intervention in prices. The apparent contradiction is resolved by recognizing that when taxes are levied to raise revenue, optimal rates minimize their effect on resource allocation, while here the sole purpose of taxes is to modify use of resources.

C. Organization of Producers

With a single producer, $\sigma = 1$ and the difference between the control regimes is reflected only in the size of the product $s\eta$. As we saw earlier, under quota, all producers are politically active and the degree of their organization does not affect the equilibrium reached. Similarly, if in a tax regime all producers are organized in a lobby and operate in unison,

$\sigma = 1$ and the number of producers or their organizations does not affect equilibrium. But a price regime is conducive to free riding.

The explanation for the importance of cooperation in determining the political equilibrium of an industry is simple and the situation is familiar to observers of administrative controls. With a quota, every producer is trying to increase his or her own utilization of the controlled factor and so does a lobby arguing for its members. The political activists present convincing arguments aplenty. For the government it is relatively easy to yield to the pressure of a particular individual or lobby—the quantitative effect is relatively small. Alternatively, in a price regime with a uniform tax rate, the government is standing firmer—a concession to one producer or group is a concession to the whole industry. Consequently, the greater the amount of free-riding in a price regime, the stronger the comparative social advantage of this control.

By conventional wisdom, heterogeneity of the production units argues in favor of price control as prices, being uniform, economize on information while, with heterogeneous producers, efficiency calls for unequal, individually tailored quotas. This argument was qualified by Weitzman (1974) who noted that for iterative planning there is no significant information difference between a price and a quota regime. In a political environment, between firm allocation is efficient and heterogeneity in production affects equilibrium allocation only to the extent that a more heterogeneous industry may tend to be more loosely organized and have a larger number of free riders.

D. A Caveat

The intuitive interpretations, and indeed Proposition 1 and particularly its Part (i), should be accepted with care. The proposition is defined for the conditions of a political equilibrium. The equilibrium ratio s is endogenously determined; and the elasticity of the factor demand is also in general an endogenous magnitude. These variables are components of a political equilibrium. The proposition, as indicated, *characterizes* the equilibrium: if in equilibrium (with negative externalities) $|\sigma/\eta s| < 1$, price control dominates. It may

however happen that even for an elastic demand and a comparatively small lobby, the equilibrium value of s will be so small that $|\sigma/\eta s| > 1$, and then a quota regime will be more efficient. The situation is simpler for an inelastic demand and $\sigma = 1$; it is then assured that $|1/\eta s| > 1$ and a quota control clearly dominates.

VII. Political Contributions

While the characterization of the allocation parameters was based in the first stage of the calculation of equilibrium solely on the common property of political efficiency, the contributions depend on the specific political process. The analysis in the paper is confined to Grossman and Helpman's (1994) model which employs the procedure of a menu auction. As before, the analysis is conducted under the assumption that all organized producers are members of a single industrial lobby and that under a price regime some producers may not participate in the political game. As indicated earlier, with our structural assumption of constant political cost and effect, only the aggregate reward, C , is determined in the political equilibrium; the individual c^i values are set by the lobby. The model conceptualizes the political process as a two-stage noncooperative auction game. In the first stage, lobbies, which may have opposing interests, offer political contributions for changes in policy parameters. In the second stage, the government chooses parameters that maximize its utility which is, as in eq. (3), a weighted sum of social welfare and political rewards. The perfect Nash equilibrium of this game is not unique, but "truthful" strategies lead to unique Nash equilibria which are coalition proof and focal.⁹ With a single lobby, as is the situation we analyze, the government gets just its reservation utility and all surplus in the polity is received by the producers.

⁹ Marginally and when contribution schedules are differentiable, all politically efficient equilibria are truthful: at points of tangency in Figure 1, producers under quota offer $\partial c/\partial q = \pi_q$, and in a tax regime, they offer $\partial c/\partial t = q$; in both cases the marginal contribution is equal to the true value of an additional unit of the negotiated control.

The government reservation utility is given by $V(q_1^s, \dots, q_N^s)$. Accordingly

$$C = V(q_1^s, \dots, q_N^s) - V(q_1^{po}, \dots, q_N^{po}). \quad (14)$$

In Figure 1, the payment to the government is represented by the distance, on the contract curve, from the q axis to the point a . The political contributions grow with the deviation of equilibrium allocation of the regulated factor from the social optimum.

Using eqs. (14) we conclude:

Proposition 2: *Consider the setup of Proposition 1 with negative externalities and suppose that the political process follows the procedure of a menu auction. Then, a quota (price) regime induces a larger level of political contributions, if and only if $|\sigma/\eta s| < (>)1$.*

If the political process follows the procedure of a menu auction, then Propositions 2 completes, together with Part (i) of Proposition 1, the main answers to the question of *prices or quantities*: a. the comparative advantage of either of the regimes can be determined unambiguously for negative externalities; b. with negative externalities, the condition for price regimes to be more efficient both in yielding resource allocation closer to the social optimum and in saving on political pressure and rewards, is that $|\sigma/\eta s| < 1$; c. with positive externalities the comparative efficiency of either of the regimes cannot be determined in general terms.

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Figure 1: Construction of Political Equilibrium

Figure 2: Gains From Political Influence--Prices vs. Quantities

CHAPTER 5: TIER PRICING IN CLOSED AND OPEN ORGANIZATIONS

1. Introduction

One of the problems of Agricultural cooperatives is the dilemma between two objectives: 1) economic efficiency; 2) balanced budget. The first requires marginal pricing, while the second implies average pricing. The solution to the above problem may be found in the form of some nonlinear pricing scheme. A nonlinear pricing scheme, which is simple and popular in input markets (irrigation) is the tier pricing method. Below, we examine this pricing method in an input market, under two alternatives: 1) fixed number of firms; 2) free entry. The results may be applied to agricultural cooperative to conclude that tier pricing may achieve the first best in closed cooperatives, but is always inefficient in open organizations.

Increasing block-rate pricing is advocated by many economists (*e.g.*, Wichelns and Cone 1989, Yaron 1991, and Zusman 1997) as allowing of separation of efficiency from income transfer. With increasing block-rate pricing users are charged the marginal social cost for the marginal quantities but the average water price is lower. On the face of it, such pricing combines the best of all worlds — at the margins resource users face the correct incentive, while the total “amount” which they pay is moderate. This possibility is used to justify the use of block-rate pricing in mitigating the effect of lobbying and political resistance and in cases where subsidization of the farm sector is critical. Indeed, the block-rate pricing regime is applied to regulate irrigated agriculture, world-wide. Particular examples include Californian water utilities and the Israeli water agency.

In this paper we analyze the performances of increasing block-rate pricing considering long-run industry equilibrium under free entry and assess its efficiency relative to flat-rate pricing. Assuming first-best policy is feasible, we show that while flat-rate pricing at level of social marginal cost implements social optimum, an increasing block-rate pricing can never achieve it. The basic intuition goes as follows. Consider two types of firms the first

faces flat-rate pricing and the second faces increasing block-rate pricing both, however, face the same marginal price equaling the social marginal cost. Clearly, firms of the second type have lower cost functions and thus lower average cost functions. Consequently, industry equilibrium of the second type is characterized by: lower product price, more firms, higher production, and higher water utilization than that of flat-rate pricing. Since flat-rate pricing leads to social optimum, we conclude that block-rate pricing distorts it.

We then take a second-best point of view, considering circumstances under which first-best social optimum is impossible. Commonly, social concerns different from economic surplus may restrict governmental intervention, calling for second-best optimum. We analyze two such cases: preservation of family farms and supplying of agricultural product at a level higher than the socially optimal one. In contrast to the first-best case, when policy is subject to preservation of family farms, we show that block-rate pricing with the highest block at the marginal social cost of water production implements social optimum. However there is no water pricing which implements social optimum subject to constant level of the agricultural product.

Lobbying and political pressures, commonly, aimed at the water price itself. To model such situations we introduce a type of reforms characterized by constant average water price. Economists often assert that such a reform that increases the marginal price toward the marginal social cost or even higher, is a step in the right direction. Our analysis, however, shows the opposite, the optimal marginal price subject to constant average water price is lower than the social marginal cost of water production. It is worthwhile to note that this finding is consistent with the general second-best theory: with several sources of inefficiency, correcting only some may reduce welfare.

2. Modeling the Market for Irrigation Water

We model two sectors of the economy: 1) the irrigated agricultural sector, which utilizes water for irrigation and 2) the water supplier, which is assumed to be a regulated public utility. In the background of the model there is a government, which regulates the water supply and consumers who demand the agricultural product. It is worth mentioning that the model is valid also for cases in which irrigation imposes negative external effects on current or future generations of consumers .

The Water Utility

Water is produced and delivered by a regulated public-utility with a cost structure represented by the convex and well behaved function $C(W)$, where $W = Nw$ is the total industry water utilization, N is the number of identical farms and w is the per-farm water utilization. The function $C(W)$ subsumes the prices of production factors, which are required for pumping and delivering water. By assumption, these prices are given for the irrigation sector. The function C includes any external effects that water utilization in agriculture may impose on other sectors in the economy in the present or in the future.

The regulated utility implements a charge function $r(w)$. In general, this function may take many forms. In this paper, however, we limit our attention to the following form:

$$r(w) = p_w(w - \bar{w}) \quad \forall w > \bar{w}, \quad (1)$$

where p_w is the water price per acre-foot and $\bar{w}$ is the quantity given free of charge. In the sequel we consider two distinct cases, in the first $\bar{w} > 0$, the user then faces an *increasing block-rate pricing*. The second case is where $\bar{w} = 0$, equation (1) then reduces to

$$r(w) = p_w w, \quad (2)$$

and the user faces *flat-rate pricing*.

The Irrigated Agricultural Industry

The irrigated agricultural industry consists of N identical farmers who utilize water, w , for irrigation. The farming technology is represented by a concave, differentiable production function $y = f(w, x)$, where y denotes output and x stands for expenditure on other inputs. Both, w , and x are assumed to be normal production factors. The inverse demand function for (irrigated) agricultural products is $\rho(Y)$, where Y is the total industry output, $Y = Ny$.

The sole interest of each farmer is the maximization of his net profit, π , that is each farmer solves the following optimization problem

$$\max_{w, x} \rho f(w, x) - x - \tau(w). \quad (3)$$

The first order conditions describing the farmer's behavior with respect to w and x are given by

$$0 \leq \rho f_w \leq \tau_w \quad \text{and} \quad \rho f_w (w - \bar{w})(\rho f_w - \tau_w) = 0, \quad (4)$$

and

$$\rho f_x - 1 = 0, \quad (5)$$

where subscripts on f and τ denote partial derivatives. In the sequel, we assume that equation (4) reduces to $\rho f_w - \tau_w = 0$ meaning that all firms operate at the highest block. Equations 4 and 5 can be solved for the farmer's factor-demand schedules $w(\rho, \tau_w)$ and $x(\rho, \tau_w)$.

For the analysis below it is useful to consider also the farmer's cost minimization problem:

$$\min_{x, w \geq 0} \tau(w) + x \quad \text{S.T.} \quad f(w, x) \geq y, \quad (6)$$

with the associated first order conditions:

$$\tau_w - \lambda f_w = 0, \quad (7)$$

$$1 - \lambda f_x = 0, \quad (8)$$

and

$$f(x) - y = 0 \quad (9)$$

where λ is the Lagrange multiplier.

Note that the above first-order conditions, and thus the conditional factor demand functions $x(r_w, y)$, $w(r_w, y)$ and the Lagrange multiplier $\lambda(r_w, y)$, depend on $r(w)$ only through its derivative, r_w . The cost function for the case of block-rate pricing is given by:

$$c^b(r(w), y) \equiv c^0 + p_w[w(p_w, y) - \bar{w}] + x(p_w, y) + \lambda(p_w, y)(y - f(w, x(p_w, y))), \quad (10)$$

where c^0 is a set-up cost. The cost function can be used to derive the marginal and average cost functions. Employing the Envelope Theorem we get marginal cost equals the Lagrange multiplier:

$$mc^b(p_w, y) = \frac{\partial c^b(r(w), y)}{\partial y} = \lambda(p_w, y), \quad (11)$$

and average cost:

$$ac^b(p_w, \bar{w}, y) = \frac{c^b(p_w, \bar{w}, y)}{y}. \quad (12)$$

The cost, average cost, and marginal cost functions under flat-rate pricing (c^f , mc^f , ac^f , respectively) can be derived as a special case in which $\bar{w} = 0$.

Examination of (10), (11), and (12) leads to the following observation.

Observation 1: *Given effective block-rate and flat-rate pricing with the same p_w , the following holds:*

- i. *The marginal cost of a firm which faces block-rate pricing is identical to that of a firm which faces flat-rate pricing.*
- ii. *The average cost of a firm which faces increasing block-rate pricing is lower than that of a firm which faces flat-rate pricing.*

The competitive industry equilibrium in the long run with free entry, w^c, x^c, N^c , is given by the solution to the following first-order conditions:

$$\rho(Ny)f_w - r_w = 0, \quad (13)$$

$$\rho(Ny)f_x - 1 = 0, \quad (14)$$

$$\rho(Ny)f(w, x) - x - r(w) - c^0 = 0. \quad (15)$$

The first two conditions are restatement of the producer's first-order conditions but with endogenous market price for the agricultural product. The last is the familiar zero-profit condition characterizing industry with free entry.

3. Welfare Maximization

The welfare analysis of resource allocation proceeds in two stages. The first assume a predetermined number of firms and is thus associated with the short run. The second stage deals with the characterization of the socially optimal number of firms in the industry and is thus relevant for the long run.

Social Choice in The Sort Run

Social welfare is represented by the total economic surplus, that is,

$$V(w, x, N) = \int_0^{Nf(w, x)} \rho(z) dz - Nx - C(Nw) - Nc^0. \quad (16)$$

As the number of firms is fixed at $\bar{N}$ at this stage, the short-run social optimum is found by maximizing $V(w, x, \bar{N})$ with respect to w and x , yielding the first order condition:

$$\rho(\bar{N}y)f_w - C_w = 0. \quad (17)$$

and

$$\rho(\bar{N}y)f_x - 1 = 0, \quad (18)$$

meaning, that at the short-run social optimum: 1) the value marginal product of water in agriculture should be equal to the social marginal cost of water supply, and 2) the value marginal product of expenditure on other input is unity. We now turn to the socially optimal industry size.

Social Choice in the Long Run

In the long-run, the number of firms in the industry, N , is endogenously determined. The social planner's optimal choice is given by

$$(w^s, x^s, N^s) = \arg \max_{w, x, N} [V(w, x, N)], \quad (19)$$

and an optimum is characterized by the first order conditions:

$$\rho(Ny)f_w - C_W = 0, \quad (20)$$

$$\rho(Ny)f_x - 1 = 0, \quad (21)$$

$$\rho(Ny)f(w, x) - x - C_W w - c^0 = 0. \quad (22)$$

Condition (22) states that the long-run social optimum requires the firm production to take place at a level in which the profit is zero, if water were priced at its marginal cost. Alternatively, conditions (20) and (22) imply that at the optimum

$$\frac{C_W}{f_w} = \frac{x + C_W w + c^0}{f(w, x)}, \quad (23)$$

meaning that each firm operates where its marginal cost equals average cost from the society point of view ($mc^s = ac^s$).

4. First-Best Regulations

In our analysis, the government may use either of two alternative instruments of intervention: flat-rate or increasing block-rate pricing. The implementation effects of each of the control regimes on the private first-order conditions, the equilibrium production level, water utilization, and number of firms in the industry are examined. We begin with the short run and then turn to our main findings concerning the inefficiencies of increasing block-rate pricing in the long run.

Regulation in the Short Run

To find the optimal policy, the government should maximize social welfare with respect to the policy instrument subject to the private behavior as expressed by the farmer's factor demands. In the case of flat-rate pricing, the maximization problem is:

$$\max_{p_w} V(w(p_w), x(p_w), \bar{N}) \quad (24)$$

yielding the first-order condition

$$\begin{aligned} \frac{\partial V}{\partial p_w} &= \frac{\partial V}{\partial w} \frac{\partial w}{\partial p_w} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial p_w} \\ &= N[\rho(Ny)f_w - C_W] \frac{\partial w}{\partial p_w} + N[\rho(Ny)f_x - 1] \frac{\partial x}{\partial p_w} = 0. \end{aligned} \quad (25)$$

The second term on the last line vanishes by the private first-order condition with respect to x (Equation 5). Thus condition (25) reduces to $\rho(Ny)f_w = C_W$, which is the first-order condition for social optimum. Comparing the latter with the private first-order condition with respect to w ($\rho f_w = p_w$) proves that a flat-rate-pricing regime in which $p_w = C_W$ implements social optimum in the short run.

In the case of increasing block-rate pricing the government policy is characterized by two parameters: p_w and $\bar{w}$. In principle, both must be chosen optimally to maximize V . However, in the short run N is given exogenously and $\bar{w}$ does not affect the farmer's factor demand. Thus, the analysis is identical to the case of flat-rate pricing. That is, setting the

highest block rate to be equal to the social marginal cost of water production implements social optimum in the short run.

Both instruments achieve efficiency in the short run, it is only income distribution that differ between them. We now turn to the main point of the paper, showing that this separation between efficiency and income distribution is no longer valid in the long run. That is to say, in the long run any attempt to subsidize farmers (transfer income) via block-rate pricing distorts efficiency.

Regulations in the Long Run

The government now maximizes social welfare subject to the farmer's behavior and free entry. In the case of flat-rate pricing, the maximization problem is:

$$\max_{p_w} V(w(p_w), x(p_w), N(p_w)) \quad (26)$$

yielding the first-order condition

$$\begin{aligned} \frac{\partial V}{\partial p_w} &= \frac{\partial V}{\partial w} \frac{\partial w}{\partial p_w} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial p_w} + \frac{\partial V}{\partial N} \frac{\partial N}{\partial p_w} \\ &= N[\rho(Ny)f_w - C_W] \frac{\partial w}{\partial p_w} + N[\rho(Ny)f_x - 1] \frac{\partial x}{\partial p_w} \\ &\quad + [\rho(Ny)y - x - C_W w - c^0] \frac{\partial N}{\partial p_w} = 0. \end{aligned} \quad (27)$$

Once again, by comparison to the conditions for competitive industry equilibrium, (13) – (15), it is immediately seen that flat-rate pricing regime in which $p_w = C_W$ implements long-run social optimum.

In contrast to flat-rate pricing, strictly increasing block-rate pricing *always* leads to a loss of welfare. This result is, formally, stated in Proposition 1.

Proposition 1: *Consider a regulation of a competitive industry in the long run by means of increasing block-rate pricing. Then,*

- i. The long-run equilibrium is inefficient,*

If, in addition, the government sets the highest block price at the marginal social cost of water production, $p_w = C_W$, the regulated equilibrium is characterized by the following properties:

- ii. *The equilibrium price of agricultural product is lower than the socially optimal level.*
- iii. *Total agricultural production is larger than the socially desired levels.*
- iv. *Total water utilization is larger than socially desired.*
- v. *The firm production level is smaller than the scale efficient level.*
- vi. *The number of firms is larger than socially desired.*

Proof: In the current context, efficiency conditions are the same as the long-run-social optimum for which the necessary and sufficient conditions are given by equations (20), (21), and (22). Comparing these to the private first-order conditions under block-rate pricing reveals that for block-rate pricing to achieve social optimum its highest block must be set equal to C_W . But then, unless $\bar{w} = 0$, conditions (22) is violated. That is to say, only degenerate block-rate pricing can achieve social optimum.

By Observation 1, the marginal cost functions under flat-rate and block-rate pricing coincide but the average cost under the latter is below to that of the former. Consequently, the minimum of the average cost function under strictly increasing block-rate pricing is to the left of that of under flat-rate pricing, implying smaller production on each farm (left-side Figure 1). The market consequence of Observation 1 is a lower equilibrium price, implying too much aggregate production (right-side Figure 1) and water utilization. Finally, since each farm produces less output than under a flat-rate pricing, the number of farms must be greater to accommodate the rise in total output. ■

The implications of the proposition deserve a double emphasis. By Proposition 1, *first-best social optimum is not implementable with strictly increasing block-rate pricing, a structure of block pricing that leads to the first best social optimum, simply does not exist.*

Marginal Reforms

In the previous subsection we analyzed the relative efficiency of the two regulation regimes, namely we compared the long-run equilibrium under the two pricing methods. However, often, governments reform their policy in steps and, hence, it is of interest to investigate the impact of a marginal reform. The effect of marginal reform is studied via infinitesimal changes in $\bar{w}$, where as $\bar{w}$ approaches zero the regulation regime changes from increasing block-rate to flat-rate pricing.

To facilitate the analysis we introduce a framework for comparative static analysis of the equilibrium conditions under increasing block-rate pricing. The analysis is based on conditions for long-run competitive equilibrium:

$$\rho(Ny) - mc^b(y) = 0 \quad (28)$$

and

$$\rho(Ny) - ac^b(y) = 0, \quad (29)$$

with y and N as endogenous variables and $\bar{w}$ as an exogenous parameter. We consider a reform that preserves the highest block at the social marginal cost of water production, but increases $\bar{w}$. Beginning at $\bar{w} = 0$, we then have a gradual change from flat-rate pricing to increasing block rate pricing (with highest block fixed at C_W).

Totally differentiating (28) and (29), we find

$$\begin{bmatrix} N\rho' - \frac{\partial mc}{\partial y} & y\rho' \\ N\rho' & y\rho' \end{bmatrix} \begin{bmatrix} \frac{\partial y}{\partial \bar{w}} \\ \frac{\partial N}{\partial \bar{w}} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{-p_w}{y} \end{bmatrix}, \quad (30)$$

where ρ' denote the derivative of ρ with respect to y . The solution for the system in (30) is:

$$\frac{\partial y}{\partial \bar{w}} = \frac{-p_w}{y \frac{\partial mc}{\partial y}} < 0, \quad (31)$$

and

$$\frac{\partial N}{\partial \bar{w}} = -\frac{(-p_w)(N\rho' - \frac{\partial mc}{\partial y})}{\frac{\partial mc}{\partial y} \rho' y^2} > 0 \quad (32)$$

which implies

$$\frac{\partial Y}{\partial \bar{w}} = \frac{\partial N}{\partial \bar{w}} y + N \frac{\partial y}{\partial \bar{w}} = \frac{-p_w}{y\rho'} > 0. \quad (33)$$

The following proposition characterizes impact of such a reform.

Proposition 2: *A marginal regulation reform from increasing block-rate, with the highest block at the social marginal cost, toward flat-rate pricing decreases the number of firms, increases output per firm, decreases total agricultural production, and most importantly, increases total economic surplus.*

proof: It is only left to show that

$$\frac{\partial V(w, x, N)}{\partial \bar{w}} = \frac{\partial V}{\partial w} \frac{\partial w}{\partial \bar{w}} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial \bar{w}} + \frac{\partial V}{\partial N} \frac{\partial N}{\partial \bar{w}} < 0, \quad (34)$$

for all $\bar{w} > 0$. To see this, note that when $p_w = C_W$ the first two terms on the right of the equality sign vanish by the private first-order conditions. But, $\partial V / \partial N < 0$ since condition (15) is full filed and $r(w) < C_W$ w . This and (32) proves the assertion in (34). ■

The implications of Proposition 2 should be emphasized. Given that the highest block is fixed at C_W , the optimal increasing block-rate is a *flat-rate pricing*. This summarizes our finding concerning the absolute efficiency of the two regimes, when the criterion for comparison is total economic surplus. Thus far, the control regimes, were compared as first-best regulations. In the next section we turn to second-best regulations.

5. Second-Best Regulations

Social concerns other than economic surplus are often observed, distorting first best in sense of the previous section. We study below two such restrictions: constant number of family farms and constant level of the agricultural product. The interpretation below is that these cases indeed induce second-best situation. However, when welfare is directly affected by the social concern they may represent first-best as well.

Economists (*e.g.*, Zusman 1997) often argue that the water pipe is an efficient channel for subsidization. The usual justifications are that such a transfer is associated with low transaction cost and reaches directly the target population — the farmers. These are appealing arguments and raise a question about the appropriate method for second-best implementation. In particular, does discounted flat-rate pricing or increasing block-rate one perform best as a second-best regulation.

Constant number of farms

In many developed countries, the existence of family farms is considered as a social value. A notable example is the European community, where governments are willing to and actually invests considerable amounts of resources in the agricultural sector in order to preserve the number of firms in the industry. We show below that in such cases second-best is implementable by an increasing block-rate pricing.

The planner's maximization problem is

$$\max_{w,x,N} V(w,x,N) \text{ subject to } N = \bar{N}, \quad (35)$$

where $\bar{N}$ is the desired number of firms, assumed to be higher than in first-best equilibrium.

The associated first-order conditions with respect to w , x , and N are:

$$\frac{\partial V}{\partial w} = \rho(Ny)f_w - C_w = 0, \quad (36)$$

$$\frac{\partial V}{\partial x} = \rho(y)f_x - 1 = 0, \quad (37)$$

and

$$\frac{\partial V}{\partial N} = \rho(Ny)f(w, x) - x - C_W w - c^0 + \mu = 0, \quad (38)$$

where μ is the Lagrange multiplier. We now ready to state the following proposition.

Proposition 3: *Consider social optimum subject to a certain number of farms. Then,*

- i. The restricted social optimum is implementable by block-rate pricing in which $p_w = C_W$ and $\bar{w} = \mu/C_W$.*
- ii. If $\bar{N} > N^s$ then the firm scale is smaller and agricultural output is greater than their respective level at the unrestricted social optimum.*

Proof: *i.* Substitution of the suggested block-rate pricing into the conditions for competitive industry equilibrium (13), (14), and (15) yields the first-order condition for social optimum (36), (37), and (38).

ii. When $\bar{N} > N^s$ block-rate pricing with $p_w = C_W$ and $\bar{w} > 0$ implements the restricted social optimum. By Proposition 1, we know that such pricing result in too small firms and too high agricultural output. ■

Constant agricultural product

Self production of agricultural product at a certain level arises under variety of circumstances. For example, fresh food is a subsistence need in many developing countries, while in other cases countries may want to sustain a capability of agricultural production for emergency situations. The social planner, in this case, needs to solve

$$\max_{w, x, N} V(w, x, N) \text{ subject to } Y = Nf(w, x), \quad (39)$$

where Y , the target level of the agricultural product, is assumed to be higher than the first-best level. The associated first-order conditions are:

$$(\rho(Ny) + \mu)f_w - C_W = 0, \quad (40)$$

$$(\rho(Ny) + \mu)f_x - 1 = 0, \quad (41)$$

$$(\rho(Ny) + \mu)f(w, x) - x - C_W w - c^0 = 0, \quad (42)$$

where μ is the Lagrange multiplier. The characterization of the restricted social optimum is given by the following proposition.

Proposition 4: *Consider social optimum subject to a certain level of the agricultural product. Then,*

- i. The firm scale is equal to (smaller than) the firm scale at the unrestricted social optimum if the marginal cost of water production is constant (increasing).*
- ii. The restricted social optimum is not implementable by water pricing alone.*

Proof: *i.* We commence with constant marginal cost. Conditions (40) and (42) imply that at the restricted optimum

$$\frac{C_W}{f_w} = \frac{x + C_W w + c^0}{f(w, x)}. \quad (43)$$

Condition (43) is identical to condition (23). Hence when C_W is constant the optimal scale is the same as in the case of first-best regulation. We turn now to the case of increasing marginal cost. Since at the restricted optimum water utilization is larger so is C_W . But, conditions (40) and (41) reveal that at higher marginal cost water utilization decreases while x does not change, implying smaller scale.

ii. The individual behavior satisfies $\rho(Y)f_x - 1 = 0$ but restricted social optimum requires $(\rho(Y) + \mu)f_x - 1 = 0$ for the same Y . Obviously they are not satisfied simultaneously. Since the individual behavior with respect to x is not affected by the water pricing, it is clear that intervention by water-pricing alone can not induce satisfaction of the requirement for social optimum. Note, however, that a product subsidy equal to the Lagrange multiplier μ does implements the restricted social optimum. ■

When the marginal cost of water production is constant, the message of the proposition is as follows: If the regulator were to change the level of the agricultural product, the efficient way is to adjust the number of firms and leave their size unchanged.

6. Mean Price Preserving Reforms

Governmental intervention, more often than not, induces lobbying and political pressure. Interest groups organize in order to modify policies: either to fend-off threats or to exploit opportunities. Farmers in many developed countries have been organized in powerful political lobbies, which struggle, effectively, against any attempt to modify policies towards directions that hurt the farm population. In particular farmers are willing to use the political system to eliminate rises in water prices. The social planner in this case cannot achieve a first-best social optimum and is forced to a second-best.

Israel is an example of a country with effective lobby of the farm sector. The Israeli farmers, however, agreed to an increase in the marginal water price in return for establishment of lower blocks, so as to preserve the average price. Economists (*e.g.*, Zusman 1997) often assert that a reform which increases the marginal price but preserves its average, is a step in the right direction. The effect of such a reform on welfare is exactly the question that is dealt with below.

The reforms

To facilitate the analysis we employ the framework for comparative static analysis of the equilibrium conditions, under increasing block-rate pricing, which was introduced above. Once more, the analysis is based on conditions (28) and (29), with y and N as endogenous variables and $\bar{w}$ as an exogenous parameter. However, we now introduce a relationship between $\bar{w}$ and p_w , such that the average price is preserved. To this end, let $\frac{p_w(w-\bar{w})}{w} = \text{constant}$. It follows that

$$\frac{\partial p_w}{\partial \bar{w}} = \frac{p_w}{w - \bar{w}}. \quad (44)$$

We can now model the mean price preserving reform as an increase of $\bar{w}$ with an accompanied change in p_w in accordance to equation (44). By total differentiation of (28) and (29), we now find

$$\begin{bmatrix} N\rho' - \frac{\partial mc}{\partial y} & y\rho' \\ N\rho' & y\rho' \end{bmatrix} \begin{bmatrix} \frac{\partial y}{\partial \bar{w}} \\ \frac{\partial N}{\partial \bar{w}} \end{bmatrix} = \begin{bmatrix} \frac{\partial mc}{\partial p_w} \frac{p_w}{w-\bar{w}} \\ 0 \end{bmatrix}. \quad (45)$$

The solution to (45) is

$$\frac{\partial y}{\partial \bar{w}} = \frac{\frac{\partial mc}{\partial p_w} \frac{p_w}{w - \bar{w}}}{-\frac{\partial mc}{\partial y}} < 0 \quad (46)$$

and

$$\frac{\partial N}{\partial \bar{w}} = \frac{N \frac{\partial mc}{\partial p_w} \frac{p_w}{w - \bar{w}}}{\frac{\partial mc}{\partial y} y} > 0 \quad (47)$$

which implies $\partial Y / \partial \bar{w} = 0$. That is, such a reforms does not change the total quantity of the agricultural product, and hence, the market price is unaffected as well. The latter implies that such a reform shifts the minimum average cost horizontally but leaves its level unchanged.

Figure 2 graphically illustrates the effect of such reforms on the firm cost structure. Firstly, consider a flat-rate pricing in which $p_w = C_W$. The marginal and the average cost functions associated with this case, ac^s and mc^s , are drawn in Figure 2, their intersection indicates the socially optimal scale of each firm y^s . Secondly, introduce an increasing block-rate pricing in which $p_w = C_W$, as discussed above, this shifts the ac curve down while the mc stays. The new intersection is to the left of y^s , implying smaller firm size (y^b in Figure 2). Thirdly, suppose that $\bar{w}$ decreases to zero with accompanying fall in p_w so as to preserve the average water price. Since the marginal cost function shifts down and the minimum average cost function shifts to the right, the firm size increases. The respective intersection (y^f in Figure 2) is to the right of y^s , but note that this is not necessarily the case.

Regulation subject to mean price preserving reforms

Finding the optimal water pricing subject to such reforms requires welfare maximization with respect to p_w . The resulting first-order condition is

$$\begin{aligned} & N(\rho(Ny)f_w - C_W) \frac{\partial w(p_w)}{\partial p_w} \\ & + N(\rho(Ny)f_x - 1) \frac{\partial x(p_w)}{\partial p_w} \\ & + (\rho(Ny)f(w, x) - x - C_W w - c^0) \frac{\partial N}{\partial p_w} = 0, \end{aligned} \quad (48)$$

The consequences of this maximization are summarized in the following proposition.

Proposition 4: *Consider water-pricing reforms from block-rate one in which $p_w = C_W$ and $\bar{w} > 0$ toward flat-rate one in which $p_w < C_W$ and $\bar{w} = 0$ such that the mean water price is preserved. Then,*

- i. *The optimal water pricing is characterized by $p_w < C_W$.*
- ii. *The optimal firm size is smaller than the first-best firm size.*
- iii. *If the output elasticity of the conditional water demand is greater than unity then $\bar{w} > 0$.*
- iv. *For flat-rate pricing to be optimal subject to such reforms, the output elasticity of the conditional water demand must be smaller than unity.*

proof: i. Consider a block-rate pricing in which $p_w = C_W$. At this point, the first two terms in the planner's first-order condition (48) vanish. But, the third is negative, implying that a decrease in p_w raises welfare.

ii. We will now show that optimal firm size subject to the reforms is to the left of y^s (Figure 2). To this end, we need to characterize conditions under which (48) vanishes. Since, $\frac{\partial N}{\partial p_w} = -\frac{N}{y} \frac{\partial y}{\partial p_w}$ by (35), (37) and (38). Expression (48) becomes

$$\begin{aligned}
 & N(\rho(Ny)f_w - C_W) \left(\frac{\partial w}{\partial p_w} \right) \\
 & + N(\rho(Ny)f_x - 1) \left(\frac{\partial w}{\partial p_w} \right) \\
 & + (\rho(Ny)f(w, x) - x - C_W w - c^0) \left(-\frac{N}{y} \frac{\partial y}{\partial p_w} \right) = 0.
 \end{aligned} \tag{49}$$

By algebraic manipulation we get

$$\begin{aligned}
 & \left(\rho(Ny) - \frac{C_W}{f_w} \right) \left(f_w \frac{\partial w}{\partial p_w} \right) \\
 & + \left(\rho(Ny) - \frac{1}{f_x} \right) \left(f_x \frac{\partial x}{\partial p_w} \right) \\
 & - \left(\rho(Ny) - \frac{x + C_W w + c^0}{y} \right) \left(\frac{\partial y}{\partial p_w} \right) = 0.
 \end{aligned} \tag{50}$$

And by $\frac{\partial y}{\partial p_w} = f_w \frac{\partial w}{\partial p_w} + f_x \frac{\partial x}{\partial p_w}$ we get

$$\frac{x + C_W w + c^0}{y} \frac{\partial y}{\partial p_w} - \frac{C_W}{f_w} f_w \frac{\partial w}{\partial p_w} - \frac{1}{f_x} f_x \frac{\partial x}{\partial p_w} = 0. \quad (51)$$

Now substitute $\frac{C_W}{f_w} \frac{p_w}{C_w}$ for $\frac{1}{f_x}$ to get

$$\frac{x + C_W w + c^0}{y} \frac{\partial y}{\partial p_w} - \frac{C_W}{f_w} \left(f_w \frac{\partial w}{\partial p_w} + \frac{p_w}{C_w} f_x \frac{\partial x}{\partial p_w} \right) = 0. \quad (52)$$

Since $\frac{p_w}{C_w} < 1$ and $\frac{\partial x}{\partial p_w}$ is positive we have

$$\frac{x + C_W w + c^0}{y} \frac{\partial y}{\partial p_w} - \frac{C_W}{f_w} \left(f_w \frac{\partial w}{\partial p_w} + f_x \frac{\partial x}{\partial p_w} \right) = (ac^s - mc^s) \frac{\partial y}{\partial p_w} < 0. \quad (53)$$

This proves that the optimal firm size subject to mean price preserving reforms is lower than the first-best firm size.

iii. We have to show that the point where the pricing become flat is to the right of y^s (see Figure 2). To see this, differentiate $(mc - ac)|_{y=y^s}$ with respect to p_w to find $\frac{\partial}{\partial p_w} (mc - ac)|_{y=y^s} = \frac{\partial w(p_w, y)}{\partial y} - \frac{w(p_w, y)}{y} > 0$ if and only if the output elasticity of the conditional water demand is greater than unity. In this case as p_w decreases the marginal cost function shifts down more than the average one, meaning that their new intersection is to the right of y^s .

iv. Immediate by the proofs for (ii) and (iii). ■

A decrease in the marginal price from $p_w = C_W$ to $p_w < C_W$, which preserve the average price, *increases* welfare. Intuitively, such a change keeps the total production constant and hence consumer surplus is unchanged. However, it increases the too-small firm size, thereby reducing distortions and gaining efficiency which lead to increase in welfare. Economists, sometimes, recommend pricing reform of the above type in attempts to equalize the marginal private price with the marginal social cost of the resource. In industries, where entry and exit are free, this may lead to poor consequences.

7. Final Remarks

The general conclusions that emerge from our analysis are: 1) Applying increasing block-rate pricing reduces net economic surplus. 2) The long-run equilibrium under increasing block-rate pricing, with the highest block fixed at the marginal social-cost, is characterized by too-small and inefficient firm size, too many firms, excess production cost, excess industrial production, over utilization of resources and external social cost. 3) Block-rate pricing with the highest block at the social marginal cost dominates flat-rate pricing as a second-best regulation subject to constant number of farms. In this case, the preservation of family farms has a social value of its own and the society is willingly sacrificing economic surplus to keep farms in the industry. 4) Water pricing alone can not implement social optimum subject to a certain level of the agricultural product. 5) Lobbying and political pressure, which force the regulator to keep the average water price at a constant level, result in optimal block-rate pricing with the highest block below the social marginal cost.

A few of our results resemble the conclusions regarding the comparative efficiency of Pigouvian taxes and subsidies in regulating external effects (*e.g.*, Kamien, Schwartz and Dolbear 1966, Polinsky 1979, Cropper and Oates 1992.) However, here, we deal with the regulation of an input market and a increasing block-rate pricing, rather than a subsidy for production and therefore, an entirely different model and analysis are required. Before concluding we emphasize a few aspects of generality.

In this paper, two blocks were used with the lower at zero. In fact, this does not impose loss of generality relative to many blocks or even more sophisticated forms of nonlinear pricing. The only factor that matters is the size of subsidization relative to first-best flat-rate pricing — the higher the subsidy the worse the distortion.

In many real cases nonlinear pricing is utilized for taxation of the recourse users, an example is an urban water use. We then have decreasing instead of increasing blocks. The results and the analysis presented in this paper allow strait-forward conclusions for decreasing block-rate pricing as well.

The results in this paper are derived under partial equilibrium model, as only one sector has been analyzed. Our inefficiency results would remain valid under general equilibrium model as well, since efficiency requires social optimum in all sector. Indirect affects to other markets may reduce the inefficiency size.

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Figure 1: Flat-Rate and Block-Rate Equilibriums

Figure 2: Mean Price Preserving Reforms

CHAPTER 6: HEDONIC COST MODELS AND THE PRICING OF MILK COMPONENTS

Since the early days of the federal milk market order system, a separate administered price has been paid for butterfat and for skim milk. Inasmuch as skim consists of protein, lactose, minerals, and water, the price of protein has essentially been the same as the price of water. Market orders now are adopting multiple-component pricing plans in order to reduce the allocative inefficiencies which the old system had engendered. The new formulae involve a separate price for butterfat, solids-not-fat, and water, or alternatively for butterfat, protein, solids-not-fat-not-protein, and water (National All-Jersey).¹ Either structure will permit a rapid increase in the price of protein relative to that of other milk components. Market order mergers mandated in the 1995 Farm Bill likely will hasten adoption of multiple component pricing and thus the protein price increases that will proceed from it.

Economists have paid extensive attention to aggregate milk supply's responsiveness to aggregate price (e.g. Chavas and Klemme; Howard and Shumway; Blayney and Mittelhammer; Adelaja; Quiroga and Bravo-Ureta; Thornton). Yet the current reforms likely will affect the ratios among, as well as aggregate levels of, milk component prices. Price ratios in turn would be expected to alter the mix of milk component quantities that farmers supply. In the short run, for example, changes in feed rations may influence protein and butterfat percentages in milk (Sutton, Bachman). Kirkland and Mittelhammer's nonlinear programming analysis of dairy cow experiment data is among the few efforts to examine such short-run impacts. In the longer run,

breeding programs and innovations in feed additives can influence component percentages even more.

In the present paper, we use a new hedonic econometric framework to assess the cost and technology of milk component production on 1,924 U.S. dairy farms. Model results are used to draw inferences about the effects of component price variation on component supplies. We find that marginal and unit feed cost decline moderately as a cow's overall milk output rises. However, those results mask a sharply increasing marginal cost of protein and a sharply decreasing marginal cost of butterfat. Milk component percentages will respond only weakly to price reform until producers switch to higher-protein-yielding cow breeds.

Hedonic Model Forms

As early as 1978, Spady and Friedlaender showed that an output aggregator in the cost function of a weakly separable technology provides the basis of an hedonic supply function. That is, hedonic supply functions reflect differences in the costs of producing goods of differing qualities. A number of studies followed Spady-Friedlaender, including Wang Chiang and Friedlaender and Teeple and Glyer. Others, such as Braeutigam and Pauly, assumed a generally nonseparable technology, eliminating the hedonic function as a distinct entity but continuing to include product characteristics as priceable outputs. In all these frameworks, characteristics have been specified in units that are incommensurable with output quantity.

In many situations, however, characteristics can be represented in terms of percentage concentrations of the product's ingredients. The acidity and texture of a fruit mix, for instance, are determined by the percentages of the fruits and additives comprising the mix. Because ingredient quantities are measured in the same units as are

product quantities, we will refer to such hedonic models as commensurable.

Commensurable hedonic supply functions have properties similar in some respects to standard, incommensurable, hedonic supply models, but in other respects to nonhedonic multiproduct cost models.

A useful way of inferring the supply effects of a new milk price structure is to determine the marginal cost of each component. In order to characterize the commensurable hedonic and nonhedonic approaches to this problem, let b be the quantity of butterfat, p the quantity of protein, and f the quantity of the fluid carrier (typically 94% water, 6% lactose and minerals) produced per cow per year on a given dairy farm. Annual milk production per cow is $y = b + p + f$. Like Kirkland and Mittelhammer, we will consider short-run, that is feed-induced, supply responses only, holding constant the farm's capital and labor inputs. Let x be the vector of feed quantities, such as concentrates and forages, fed per cow and z the vector of fixed production inputs. The cow's feed transformation function is then $T(b, p, f, x, z) = 0$. If w is the vector of feed prices corresponding to x , then feed cost per cow is

$$(1) \quad \min_x [wx | T(\cdot) = 0] = C_1(b, p, f, w, z) .$$

In some cases, it is useful to represent component quantities in terms of total output y and the percent concentration of each component. Minimized feed cost is then

$$(2) \quad \min_x [wx | T(\cdot) = 0] = C_2(y, b/y, p/y, f/y, w, z) = C_2(y, \bar{b}, \bar{p}, \bar{f}, w, z) ,$$

where $\bar{b} = b/y$ is percent butterfat concentration, $\bar{p} = p/y$ is percent protein, and $\bar{f} = f/y = (1 - b/y - p/y)$ is percent fluid carrier. Because milk's characteristics, such as its cheese yield and viscosity, are determined by the component percentages, (2) is

meaningfully regarded as an hedonic cost function. That is, it is formally equivalent to the approach in Braeutigam and Pauly.

The weakly separable versions of (1) and (2) are especially important.

Separability in nonhedonic model (1),

$$(3) \quad C_1(b, p, f, w, z) = C_1[K(b, p, f), w, z] ,$$

implies transformation function $T(\cdot) = 0$ be expressed as

$$(4) \quad K(b, p, f) = F(x, z) ,$$

where K is an aggregate output measure and F an aggregate input. Separability in hedonic model (2),

$$(5) \quad C_2([y, \bar{b}, \hat{p}, f, w, z) = C_2[H(y, \bar{b}, \hat{p}, f), w, z] ,$$

suggests instead that $T(\cdot) = 0$ be written

$$(6) \quad H(y, \bar{b}, \hat{p}, f) = F(x, z) ,$$

where H is an hedonic output function.

Expressions (4) and (6) each characterize a family of production possibility frontiers (ppf's) and, at a given input level, an effective unit of milk output. Effective output in (5) and (6) is defined on total milk production y and on the milk's characteristics as represented by its butterfat, protein, and fluid carrier percentages. Thus, it is the commensurable variant of the separable hedonic model developed in Spady and Friedlaender. Because commensurable hedonic models can be expressed in standard multioutput (nonhedonic) form, the choice between an hedonic and nonhedonic cost model is not always straightforward. However, an hedonic form has two

advantages. First, unless product quality varies greatly from one firm to another, component quantities will be highly multicollinear in cross-sectional data sets. Regressing cost on output and on the component percentages may in such circumstances improve estimation efficiency. Second, the language of an hedonic model is consistent with the way one normally thinks of productive activity, namely in terms of the quantities and qualities of the goods produced. In this sense, hedonic models have an especially natural interpretation.

Restrictions on Commensurable Hedonic Models

Consistency requires that hedonic output (6) be linearly homogeneous in the component quantities. To see this, note that cost elasticity

$$(7) \quad \epsilon_c = [(\partial C/\partial b)b + (\partial C/\partial p)p + (\partial C/\partial f)f] / C ,$$

namely the percent increase in cost as all components are scaled up in fixed proportion, equals

$$(7') \quad \epsilon_c = [(\partial C/\partial I)/C] [(\partial I/\partial b)b + (\partial I/\partial p)p + (\partial I/\partial f)f]$$

if the technology has generally separable form $I(b, p, f) = F(x, z)$.² If and only if I is linearly homogeneous in (b, p, f) , the second bracketed term in (7') equals I itself, so

$$(7'') \quad \epsilon_c = (\partial C/\partial I)(I/C) = (\partial C/\partial y)(y/C) ,$$

where ∂y indicates a unit increase in milk quantity holding percent concentrations $\bar{b}$, $\bar{p}$, $\bar{f}$ fixed. Equating (7) with (7'') gives $\partial C/\partial y = [(\partial C/\partial b)b + \partial C/\partial p)p + (\partial C/\partial f)f]/y$.

Thus, linear homogeneity of the output aggregator in the component quantities is necessary and sufficient for satisfying the requirement that the product's marginal cost

be the sum of the marginal costs of the component quantities, each weighted by its percent concentration in the product.

The simplest way to render (6) linearly homogeneous in the component quantities is to write it in the Spady-Friedlaender form $H(y, \bar{b}, \bar{p}, f) = yJ(\bar{b}, \bar{p}, f)$, where J is an hedonic percentage aggregator. J is zero homogeneous in the component quantities but need not be linearly homogeneous in the component percentages. Dropping fluid carrier proportion f to avoid linear dependence, we have

$$(6') \quad H(y, \bar{b}, \bar{p}) = yJ(\bar{b}, \bar{p})$$

with associated feed cost function³

$$(5') \quad C(H, w, z) = C[yJ(\bar{b}, \bar{p}), w, z] = C[yJ(b/y, p/y), w, z] .$$

We employ (5') and (6') to examine the cost and technology of milk production.

Compensated and Uncompensated Marginal Cost

Two types of marginal cost can be distinguished in any commensurable hedonic model. A component's *uncompensated (partial) marginal cost* reflects the cost increase as the component quantity is increased by one unit, holding quantities of all other components fixed. For example, the uncompensated marginal cost of butterfat, $\partial C / \partial b$, holds protein and fluid carrier quantities constant and hence requires that total milk volume increase by the same amount that butterfat does. In contrast, a component's *compensated marginal cost* reflects the increase in cost as the component's share of output is increased by one percentage point, holding total output fixed. The compensation required to keep total output constant is that the share of the component excluded from the specification must fall by one percentage point, since the shares of remaining components included in

the specification are held fixed. Thus, for example, the compensated marginal cost of butterfat in (5') is the cost effect of increasing butterfat percentage b by one point and reducing the percentage of excluded ingredient f by one point. Reducing f by one point is what is required in order to hold output y constant, since protein percentage $\hat{p}$ is held fixed.

Differentiating (5') with respect to butterfat percentage gives the compensated marginal cost of butterfat:

$$(8) \quad dC/d\bar{b} = dC/db|_{y^*, \hat{p}^*} = (\partial C/\partial H)(dH/d\bar{b}) = y(\partial C/\partial H)(dJ/d\bar{b}) .$$

To evaluate $dJ/d\bar{b}$, observe that the total derivative of percentage aggregator J with respect butterfat quantity is

$$(9) \quad dJ/db = \partial J/\partial b + (\partial J/\partial p)(dp/db) + (\partial J/\partial f)(df/db) .$$

Since y and $\hat{p} \equiv p/y$ are each constant in (8), $dy = db + dp + df = 0$ and $dp = 0$, so $db = -df$ or, equivalently, $df/db = -1$. Substituting $dp = 0$ and $df/db = -1$ into (9),

$$(9') \quad dJ/db|_{y^*, \hat{p}^*} = dJ/d\bar{b} = \partial J/\partial b|_{p^*, f^*} - \partial J/\partial f|_{b^*, p^*} = \partial J/\partial b - \partial J/\partial f .$$

Substituting (9') into (8) gives

$$\begin{aligned} dC/d\bar{b} &= (\partial C/\partial H) (y\partial J/\partial b - y\partial J/\partial f) \\ (8') \quad &= (\partial C/\partial H) [(\partial H/\partial b - J) - (\partial H/\partial f - J)] \\ &= (\partial C/\partial H) (\partial H/\partial b - \partial H/\partial f) \\ &= MC_b - MC_f , \end{aligned}$$

where MC_b and MC_f are the uncompensated marginal cost of butterfat and fluid carrier, respectively.⁴ Compensated marginal cost in a commensurable hedonic model is the

difference between the own component's uncompensated marginal cost and the excluded component's uncompensated marginal cost.

Differentiating (5') with respect to protein percentage, and applying sequence (9) - (8') while holding butterfat rather than protein percentage fixed, gives the compensated marginal cost of protein:

$$(10) \quad \begin{aligned} dC/d\hat{p} &= dC/dp|_{y^*, \bar{b}} = (\partial C/\partial H)(dH/d\hat{p}) = y(\partial C/\partial H)(dJ/d\hat{p}) \\ &= MC_p - MC_f, \end{aligned}$$

namely the difference between the uncompensated marginal cost of protein and the uncompensated marginal cost of the fluid carrier.

Net Return Maximization

Consider now the problem of maximizing a firm's return over feed cost. In general, the firm faces a distinct price P_b for butterfat, P_p for protein, and P_f for carrier, so the aggregate price of raw milk is $P_y = P_b \bar{b} + P_p \bar{p} + P_f f = P_b \bar{b} + P_p \bar{p} + P_f (1 - \bar{b} - \bar{p})$. Return over feed cost is maximized by finding the total milk quantity and butterfat and protein proportions which maximize

$$(11) \quad \pi = P_y y - C[yJ(\bar{b}, \bar{p}), w] .$$

In a length of run short enough that output y is unaffected by component proportions, first-order conditions for a net return maximum are

$$(12) \quad \begin{aligned} d\pi/d\bar{b} &= (P_b - P_f) - (MC_b - MC_f) = 0 \\ d\pi/d\bar{p} &= (P_p - P_f) - (MC_p - MC_f) = 0 \\ \partial\pi/\partial y &= P_y - \partial C/\partial y = 0 . \end{aligned}$$

The farmer adjusts milk volume and component proportions so that the marginal cost of milk is driven up to the composite price of milk, and so that the difference between the marginal cost of each included component and the excluded component is equated to the corresponding price difference. These conditions are simultaneously determined because increases in milk volume, holding component percentages constant, generally affect the differences between components' marginal costs. The distinguishing feature between a commensurable hedonic model and a nonhedonic model is that in an hedonic relation the firm optimizes with respect to differences between, rather than levels of, marginal costs and prices.

Moving price terms in (12) to the right, dividing the second condition by the first, and substituting from (9) and (10) gives the equation for allocative efficiency on the total-output-compensated expansion path:

$$\begin{aligned}
 (13) \quad d\bar{b}/d\bar{p} &= db/dp|_{y^*} = (dJ/d\bar{p})/(dJ/d\bar{b}) = (dH/d\bar{p})/(dH/d\bar{b}) \\
 &= (MC_p - MC_f)/(MC_b - MC_f) = (P_p - P_f)/(P_b - P_f) .
 \end{aligned}$$

If protein output rises by one unit, if fluid carrier quantity is adjusted to keep total milk output constant, and if input aggregate $F(x, z)$ is fixed, the amount of butterfat that must be surrendered is the difference between the protein and fluid carrier marginal cost divided by the difference between butterfat and fluid carrier marginal cost. The firm adjusts component quantities on the total-output-compensated production possibility frontier J so that the marginal cost difference between protein and carrier, considered as a ratio of the marginal cost difference between butterfat and carrier, is equated to the corresponding price difference ratio.⁵

Hypotheses

Dairy scientists have experimented extensively with the effects of feed composition on the volume and composition of milk output (Sutton, Bachman). As a broad rule, increasing the feed concentrate-to-forage ratio in the cow's diet tends to (i) increase total milk output; (ii) reduce the milk's butterfat percentage by nearly the same proportion that total milk output rises; and (iii) slightly increase the milk's protein percentage. Taking these effects together, an increased feed concentrate-to-forage ratio would have little effect on butterfat output but would raise protein output moderately and fluid carrier output substantially. Because high-concentrate rations are more expensive than low-concentrate ones, we would therefore expect the uncompensated marginal costs to be ordered

$$(14) \quad MC_b \geq MC_p \geq MC_f.$$

Comparing (14) with (8') and (10), the compensated marginal costs would be ordered

$$(15) \quad dC/d\delta \geq dC/d\hat{p}.$$

These orderings represent broad expectations only, that is, averages over the range of feasible butterfat and protein percentages. In general, marginal costs depend on the animal's genetic makeup, the type of concentrate and forage fed, and other management practices. Just as importantly, feed production possibility frontiers probably are nonlinear (Bachman, p. 343), so that marginal cost differences would vary with the point on the ppf at which the dairy farmer operates. In a competitive economy, such a point would depend in turn on prices which farm firms receive for milk components. Thus, in order to anticipate marginal cost differences more exactly, one needs to examine the output pricing structure which sample firms face.

Estimation

The most complete farm records covering more than a single state are available from the Dairy Record Processing Center (DRPC) of Raleigh, North Carolina. Raleigh DRPC provided 1993 data from 8,746 individual dairy farms. States represented were Vermont, southeastern Pennsylvania, Indiana, and most of the Southern and Border states from the eastern seaboard through Texas. DRPC data are collected monthly. Production quantities are measured electronically; costs and feed quantities are taken from farm records. Raleigh DRPC data contain more information about feed quantities, and thus about farm-level feed prices, than do data from other regional DRPCs.

On a per-cow per-year basis, the data set included total feed cost; quantity of butterfat, protein, and fluid carrier produced; expenditures on feed concentrates and forages; cow breed; performance scores of milking cows' sires; farm location; and other information such as average cow weight and pregnancy record. Feed prices paid by each farm were calculated by dividing feed quantities into feed expenditures. Insufficient data were available to distinguish between fresh and dry forage expenditures, so the latter were combined into a single forage price variable. Enumerators did not assess the cost or quantity of pasture consumed. In all, records from 1,924 farms were complete enough for statistical analysis.

Table 1 summarizes the data and defines variables. Eighty-seven percent of the herds were Holstein. Sample mean butterfat and protein percentages, and total milk production per cow, were close to the national averages (Aitchison, p. 3). Coefficients of variation of butterfat and protein percentages were predictably modest, given the high correlation across farms between butterfat and protein output per cow. Cross-farm variability in protein percentage was only half that of butterfat.

Specifications

Fixed factors z most likely to affect feed costs are the farmer's capital investments in cows and pasture. We represented cow herd quality by an indicator variable for cow breed ($D_{\text{hol}} = 1$ if Holstein, 0 otherwise) and by an index (S) of the performance rating of the cow's sire. The performance ratings were nonsignificant in all cost specifications and were subsequently removed.⁶ Mean geographic differences in pasture quality were represented by the five regional dummy variables shown in table 1. Linear homogeneity in input prices, $\lambda C(H, w_n, w_g, z) = C(H, \lambda w_n, \lambda w_g, z)$, was maintained by expressing feed concentrate price w_n and forage price w_g per unit of forage price.⁷

We first tested whether the feed cost function is separable, that is whether (5) is true given (2). Cost (2) was assumed to be translog in $(y, \bar{b}, \bar{p}, w_n/w_g, D_{\text{hol}}, D)$, in which D is the vector of regional dummy variables. Denny and Pinto (p. 260) show that the translog cost can be written in separable form if and only if, for each input price w and output level i, i' , $\alpha_{wi}/\alpha_{wi'} = \alpha_i/\alpha_{i'}$, where the α_i 's are coefficients of log outputs and the α_{wi} 's are coefficients of interaction terms between log input price and log output. In cost representation (2), input price w is w_n/w_g and outputs (i, i') are $(y, \bar{b}, \bar{p})$, so there are three such restrictions. The computed likelihood ratio statistic was 5.72, less than the critical Chi-square value of 7.81 at the 5% level with 3 degrees of freedom. We conclude there is no significant loss in explanatory power in assuming that dairy feed cost can be written in separable manner (5).

To permit maximum functional flexibility, we specified (5') as translog in $(yJ, w_n/w_g, D_{\text{hol}}, D)$ and percentage aggregator J as translog in $(\bar{b}, \bar{p})$. Thus, estimating (5') involved joint estimation of a percentage aggregator translog in the milk component percentages together with a cost function translog in the output aggregator, feed prices, and fixed inputs:

$$\begin{aligned}
(16) \quad \ln C &= \alpha_0 + \alpha_h \ln H + \alpha_w \ln w \\
&+ 1/2[\alpha_{hh} (\ln H)^2 + \alpha_{ww} (\ln w)^2] + \alpha_{hw} (\ln H)(\ln w) \\
&+ \text{indicator variable terms} + \ln w_g
\end{aligned}$$

$$\begin{aligned}
(17) \quad \ln H &= \ln y + \ln J \\
&= \ln y + \beta_b \ln \bar{b} + \beta_p \ln \bar{p} \\
&+ 1/2[\beta_{bb} (\ln \bar{b})^2 + \beta_{pp} (\ln \bar{p})^2] + \beta_{bp} (\ln \bar{b})(\ln \bar{p})
\end{aligned}$$

where $w = w_n/w_g$. Explanatory variables were divided by sample means prior to logging, so that, at sample means, $\ln H = 0$ and $\ln C = \alpha_0$. Cost functions were estimated jointly with their associated cost share equation for concentrate feeds. Parameter estimates were computed simultaneously using full information maximum likelihood (TSP Version 4.2).

Statistical Results

Estimates of (16) - (17), the translog form of (5'), are shown in table 2. R^2 of the table 2 cost equation is 0.64 and of the cost share equation 0.29, quite high for a national cross-section of farms. Since $\alpha_w > 0$ in table 2, monotonicity is satisfied at sample means. Concavity in input prices is satisfied also because $\alpha_{ww} + (\alpha_w)^2 - \alpha_w = -0.06 < 0$, ensuring that the input price Hessian matrix is negative semidefinite at sample mean.⁸ Low t-values on higher-order hedonic coefficients β_{bb} , β_{pp} , and β_{bp} reflect at least partly the multicollinearity among (17)'s regressors.⁹ (Feigenbaum and Teeples, p. 674, observed similar multicollinearity in their study of water delivery costs.) On the other hand, a likelihood ratio test of the restriction that $\beta_b = \beta_p = \beta_{bb} = \beta_{pp} = \beta_{bp} = 0$, namely that component proportions don't affect feed costs, was rejected at the 5% level (computed likelihood ratio statistic was 67.74, compared with a critical Chi-square value

of 11.07 at the 5% level and 5 degrees of freedom). We retained the full translog specification to permit maximum shape flexibility in the hedonic aggregator.

The Holstein breed variable and regional dummies were all statistically significant. At mean feed prices and milk component quantities, Holsteins were more costly to feed than were the base group, which consisted chiefly of Jersey and Guernsey cows. Holsteins produce a greater volume of milk, but with lower fat and protein concentration, than do these other breeds. The fact that a Holstein's feed costs are comparatively high at mean output levels implies that its effective output is comparatively low at mean feed quantities. Widespread use of the Holstein, therefore, suggests that its high gross output permits a high return to the dairy's fixed assets despite the animal's low feed efficiency. Turning to geographic effects, feed costs were lower in Vermont, Pennsylvania, Indiana, and in the Deep South than in the Border State control group, likely because of differences among these areas in pasture quality.

Evaluation

Separability of the milk production technology enables us to regard H as a single output and thus to consider the table 2 parameters as representative of a single-output cost function. The first question to ask about technology $H = yJ = F(x, z)$ is whether it is homothetic, that is, whether its isoquants are parallel. A technology underlying a single-output translog cost function is homothetic if and only if all interaction terms between the output quantity and input prices are zero. In table 2, the lone interaction term, α_{hw} , is negative and statistically significant. Thus, the production function by which feed concentrates and forages are converted to effective milk output appears to be nonhomothetic.

The second important question is whether dairy farms operate at an efficient scale, namely at milk component quantities which minimize feed cost per unit of effective output. Unit feed cost is a minimum if cost elasticity (η), the ratio of marginal to unit cost, is unity, that is if

$$(18) \quad \partial \ln C / \partial \ln H = \partial \ln C / \partial \ln y = \alpha_h + \alpha_{hh} \ln H + \alpha_{hw} \ln w = 1 .$$

Since, at mean output and feed prices, $\ln H$ and $\ln w$ go to zero, cost elasticity at sample mean is just $\alpha_h = 0.43$. Raising all milk components by 1% increases cost by only 0.43%. Thus, unit cost exceeds marginal cost, and unit cost is declining. Because furthermore α_{hh} is quite small, cost elasticity is largely constant and unit cost falls throughout the range of effective output.

The conclusion that dairy farmers operate in stage 1 of their feed-to-milk-components production function is unsurprising: feed must first satisfy a cow's maintenance net energy requirement before any residual is available for milk production. Maintenance net energy acts as a large negative intercept on a graph depicting milk output as a function of aggregate feed intake. Average product therefore rises throughout the early range of feed intake, and the cow's appetite is satiated before average product can begin to fall. Wilson found similarly that feedlot beef cattle operate in stage 1 of their feed-to-weight-gain production functions. This is to be distinguished from Thornton's finding that, ignoring changes in feed rations, Utah dairy production functions are linearly homogeneous in capital, labor, and land.

Substitutability of feed concentrates and forages on U.S. dairy farms appears to be modest. Input substitution elasticity at sample mean, $\sigma_{ng} = [\alpha_{ww} + \alpha_w(1 - \alpha_w)] / \alpha_w(1 - \alpha_w)$, is only 0.25 in table 2, implying that a 1% change in the slope of the (mean) concentrate-forage isoquant can be achieved with a mere 0.25% change in concentrate-

forage ratio. Conditional factor demands are therefore quite inelastic: own-price

elasticities of conditional demand for feed concentrates and forages are $\epsilon_{nn} = \alpha_w \sigma_{nn} = -0.11$ and

$\epsilon_{gg} = (1 - \alpha_w) \sigma_{gg} = -0.13$, respectively (Fuss p. 93).¹⁰ A 1% feed price increase brings only a 0.11% to 0.13% reduction in feed quantity demanded if milk component levels are fixed. All cost and substitution elasticity estimates were quite robust to changes in econometric specification, for example to elimination of geographic or breed variables.

Protein-Butterfat Tradeoffs

It is useful to see also how butterfat and protein substitute for one another in effective output H . The production possibility frontier's slope, equation (13), can be rewritten

$$(13') \quad d\bar{b}/d\hat{p} = db/dp|_y = (d \ln \bar{b} / d \ln \hat{p}) (\bar{b}/\hat{p}) .$$

If effective output is translog in the component proportions, $d \ln \bar{b} / d \ln \hat{p}$ is found by implicitly differentiating (17). Substituting into (13') gives

$$(13'') \quad d\bar{b}/d\hat{p} = [(\beta_p + \beta_{pp} \ln \hat{p} + \beta_{bp} \ln \bar{b}) / (-\beta_b - \beta_{bb} \ln \bar{b} - \beta_{bp} \ln \hat{p})] (\bar{b}/\hat{p}) ,$$

which is a highly flexible function of the component proportions.

To provide an idea of how tradeoff rates (13'') vary over the range of actual dairy production, we substituted table 2 parameter values into (17) and derived combinations of $\bar{b}$ and $\hat{p}$ that yield fixed quantities of H . Results for the unit ppf, $H = 1$, are shown in figure 1. Protein quantities on the x-axis of figure 1 range from two standard deviations below to two standard deviations above the sample mean. Since regressors in (16) and (17) are expressed per unit of their sample means, $H = y = 1$

when all component percentages are at sample means. Thus, μ in figure 1 indicates the point of mean butterfat percentage as well as protein percentage.

Despite the flexibility permitted in the translog form, figure 1 has the convex shape one normally expects of a production possibility frontier. As milk's protein percentage increases, increasing quantities of butterfat must be given up to replace a unit of protein if effective output is to be held constant. However, within the observed range of protein proportions, all butterfat-protein tradeoff rates are less than unity. And at sample means, the butterfat cost of an additional unit of protein is rather low.

Evaluating (13') at sample means gives $d\bar{b}/d\bar{p} = -(\beta_p/\beta_b)(\bar{b}/\bar{p}) = -(0.45)(1.14) = -0.51$, implying that a one-percentage-point increase in protein has required only a one-half-percentage-point reduction in butterfat in order to hold effective milk output fixed.¹¹ The difference, that is, between the marginal cost of protein and fluid carrier has been only one-half as large as the difference between the marginal cost of butterfat and fluid carrier. The sample variance of this statistic is wide because the standard error of the β_p estimate in table 2 is rather high. Yet hypotheses (14) and (15) would be confirmed even in the event β_p were zero.

If every sampled dairy farm received the same price for protein as it did for fluid carrier, optimization conditions (13) would require that protein and fluid carrier marginal costs be equated also. Every farmer would operate at figure 1's peak and there would be no sample variation to generate a production possibility frontier. Although by 1993 none of the federal marketing orders in the study area had begun pricing protein separately from the rest of the skim milk, many dairy marketing cooperatives reblend their members' returns to accomplish this same result. Reblending programs vary widely from one cooperative to another, so that price differences between protein and fluid carrier can vary substantially across farms. Cooperative price reblending provides

valuable sample price variation for drawing post-regulation inferences from regulation-era data.

Partial Marginal Costs

Partial marginal cost functions of the three milk components can, of course, be derived directly from equations (16) and (17). They are provided in the appendix. At sample mean outputs and 1993 dollars, the marginal cost of butterfat, protein, and fluid carrier production are \$0.328, \$0.173, and \$0.008 per lb, respectively, giving a weighted average marginal feed cost of milk of \$0.025/lb (\$0.26 per gallon). More insight can be gained by examining how marginal costs behave away from the sample mean. Figure 2 gives the marginal cost of butterfat, protein, and fluid carrier as the quantity of each ranges two standard deviations above and below its mean and the remaining quantities are held fixed. The marginal cost of milk, in which all three components are scaled up in fixed proportion, is shown for comparison.

Milk's marginal cost falls moderately with increased output (elasticity of marginal cost with respect to output is -0.62 at sample mean), consistent with the declining unit cost discussed above. Yet butterfat is the only milk component whose marginal cost declines with increases in the component itself. The fluid carrier's and, especially, protein's own-component marginal cost functions are positively sloped. Elasticity of butterfat, protein, and fluid carrier marginal cost with respect to own component are, at sample mean, -2.20, 2.32, and 0.26, respectively.¹² Conversely then, elasticities of component quantities with respect to marginal costs are low, suggesting that milk component supplies would be quite inelastic if feed management alone was allowed to vary. This is generally consistent with Kirkland and Mittelhammer's finding that a 1% increase in butterfat price would bring only a 0.07% increase in butterfat

production and a 0.01% increase in solids-not-fat production if ration alone were permitted to change.

Concluding Remarks

The picture of a U.S. dairy farm that emerges from this study is one of a nonhomothetic feeding technology in which cost elasticity is well below unity and nearly constant. Milk's unit and marginal cost therefore decline throughout the sample range. However, hedonic analysis of milk components shows that the moderately negative slope of milk's marginal cost function masks a strongly upsloping marginal cost function for protein and strongly downsloping marginal cost function for butterfat. In addition, dairy feeding technology is separable in the feed and output aggregates we have employed, and substitutability among both inputs and outputs is modest.

The limited range of substitution between butterfat and protein in these data reflect the relative stability of milk component price ratios during the past several decades (Jacobsen). Although many cooperatives' price reblending programs reward protein production to some extent, the old federal order pricing structure has kept protein prices generally low. Dairies have responded to this incentive by breeding cows which yield low-protein milk and in which the butterfat cost of additional protein therefore remains low as well. The adoption of multiple component pricing plans will permit protein prices to rise toward protein's marginal productivity in cheese production. However, the steeply rising marginal protein cost which we have estimated suggests that feed management adjustments will be only weakly effective in increasing protein production. Multiple component pricing will thus bring substantially higher protein prices until dairies introduce higher-protein-yielding animals, shifting marginal protein costs downward. Policy makers must be prepared to stay the course until these long-run capital adjustments permit protein prices to fall once again.

Table 1. Variables Used in Hedonic Cost Analysis

Variable	Symbol	Unit	Mean	Coefficient of Variation
Feed cost	C	\$/cow-year	976.86	0.186
Milk production	y	000lbs/cow-year	18.07	0.155
Percentage butterfat	$\bar{b}$	%	3.71	0.097
Percentage protein	$\bar{p}$	%	3.25	0.054
Feed concentrate price	w_n	\$/lb	0.089	0.286
Forage price	w_g	\$/lb	0.026	0.355
Feed concentrate price/ forage price	w	ratio	3.86	0.418
Sire quality	S	index	145.94	0.330
Holstein ^a	D_{hol}		0.87	
NonHolstein	D_{nho}		0.13	
Vermont	D_{ver}		0.12	
Pennsylvania	D_{pen}		0.26	
Indiana	D_{ind}		0.16	
Border states ^b	D_{bor}		0.31	
Southern states ^c	D_{sou}		0.15	

^a Mean of indicator variables shows percent of sample falling into respective group.

^b Border states consist of Virginia, North Carolina, Kentucky, Tennessee, and Missouri.

^c Southern states consist of Florida, Georgia, Alabama, South Carolina, Mississippi, Louisiana, and Texas.

Table 2. Estimated Hedonic Cost Function Parameters for Milk Component Production^a

Variable	Parameter	Estimate	Asymptotic Standard Error
Intercept	α_0	10.584	0.019
$\ln H$	α_h	0.434	0.040
$\ln w$	α_w	0.535	0.005
$\ln^2 H$	α_{hh}	-0.104	0.256
$\ln^2 w$	α_{ww}	0.188	0.006
$\ln H \ln w$	α_{hw}	-0.069	0.020
D_{hol}	ζ_{hol}	0.104	0.018
D_{ver}	ζ_{ver}	-0.047	0.014
D_{pen}	ζ_{pen}	-0.093	0.012
D_{ind}	ζ_{ind}	-0.073	0.016
D_{sou}	ζ_{sou}	-0.036	0.015
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$\ln \hat{b}$	β_b	0.468	0.154
$\ln \hat{p}$	β_p	0.212	0.324
$\ln^2 \hat{b}$	β_{bb}	-0.699	1.675
$\ln^2 \hat{p}$	β_{pp}	0.657	10.864
$\ln \hat{b} \ln \hat{p}$	β_{bp}	-1.920	3.755

^a Dependent variable is $\ln (C/w_g)$. Log of likelihood function: 1313.06. R^2 of cost function: 0.64.

Figure 1: Combinations of butterfat and protein percentages that provide one unit of effective milk output ($H = 1$) when total milk volume is at sample mean.

Figure 2: Marginal cost functions: milk and its components. ^a

^a A component's partial marginal cost curve is generated by varying the indicated output rate two standard deviations above and below its sample mean, holding the other two components at sample mean. Milk's marginal cost curve is generated by varying the milk output rate two standard deviations above and below sample mean, holding component percentages at sample means (3.71% butterfat, 3.25% protein, 93.04% fluid carrier)

Footnotes

1. The price of water in milk would be nonzero to the extent that the federal marketing order system continues to exert market power on behalf of producers.
2. $I(\cdot) = F(\cdot)$ refers here to a generally separable model, whether the arguments of I are component quantities or percentages.
3. For notational simplicity, cost subscript 2 in equation (5) will be suppressed.
4. To derive line 2 from line 1 in (8'), differentiate $H = yJ(b/y, p/y)$ to get $\partial H/\partial b = (\partial y/\partial b)J + y(\partial J/\partial b)$. Noting that $\partial y/\partial b = 1$ (since $y = b + p + f$), and rearranging terms, gives $(\partial J/\partial b)y = \partial H/\partial b - J$. By the same reasoning, $(\partial J/\partial f)y = \partial H/\partial f - J$.
5. If protein rather than fluid carrier were the excluded term in (6'), so that the hedonic function were instead $J(\hat{b}, \hat{f})$, differentiating J with respect to $\hat{b}$ would give the net effect of increasing $\hat{b}$ by one percentage point and reducing $\hat{p}$, the excluded term, by one point. By the same token, first-order conditions would be defined in terms of differences between the marginal cost of butterfat (or fluid carrier) and protein.
6. Sire performance rating is a bull's Predicted Transmitting Ability as defined by the U.S. Department of Agriculture in 1989 (Aitchison). Failure of the index to explain feed cost differences across farms suggests that the daughters' higher milk production comes in the form of higher total output -- and thus potentially higher return to fixed assets -- rather than in the form of higher output for a given feed input. If so, sire quality would not affect feed cost at given output levels.
7. Since forage price then acts as the feed price numeraire, the dependent variable becomes $\ln C - \ln w_g$. See, for example, Denny and Pinto (p. 260).

8. The first diagonal term in the input price Hessian matrix is $(C)[\alpha_{ww} + (\alpha_w)^2 - \alpha_w]/(w_n)^2$.

Since $C/(w_n)^2$ is positive, the entire expression is negative if $[\alpha_{ww} + (\alpha_w)^2 - \alpha_w]/(w_n)^2$ is negative. The second principal minor of the Hessian is zero.

9. As an indicator of multicollinearity, a linear regression of $(\ln \hat{b})(\ln \hat{p})$ on the other right-hand terms in (17) gave an R^2 of 0.86. Multicollinearity was much higher when nonhedonic model (1) was estimated in place of hedonic model (16) - (17).

10. The unconditional demand elasticities would be higher than these. Quiroga and Bravo-Ureta report unconditional own-price elasticities of demand on Vermont dairy farms as -0.53 for concentrates and -0.59 for forages.

11. These statements are equally valid for quantity units, such as grams, as for percentage point units since total milk output is fixed. Percentage *point* changes are, however, different from *percentage* changes, which can be represented only through the elasticity form of (13). The elasticity form is easily computed by multiplying (13) by $\hat{p}/\hat{b}$.

12. The slope on milk's marginal cost function in figure 1 is the derivative of

$$\partial C(bt, pt, ft)/\partial t = [(\partial C/\partial bt)b + \partial C/\partial pt)p + (\partial C/\partial ft)f] \text{ with respect to scale factor } t.$$

Applying the expression for a total derivative shows that this slope depends not only on the marginal cost functions' own-quantity slopes [such as $\partial(\partial C/\partial bt)/\partial bt$], but on the cross-quantity slopes [such as $\partial(\partial C/\partial bt)/\partial pt$] as well. Hence, we cannot ascribe the negative sign on $\partial(\partial C/\partial t)/\partial t$ to the negative sign of own-quantity slope $\partial(\partial C/\partial bt)/\partial bt$ alone.

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Appendix

Differentiating (16) - (17), the partial (uncompensated) marginal cost of butterfat, protein, and fluid carrier are, respectively:

$$\begin{aligned}
 MC_b = \partial C / \partial b &= (C/b) [\partial \ln C / \partial \ln H] \{\partial \ln H / \partial \ln b\} \\
 &= (C/b) [\alpha_h + \alpha_{hh} \ln H + \alpha_{hw} \ln w] \{\beta_b + (1 - \beta_b - \beta_p)(b/y) \\
 &\quad + \beta_{bb} \ln b + \beta_{bp} \ln p - (\beta_{bb} + \beta_{bp})[(\ln b)(b/y) + \ln y] \\
 &\quad + (\beta_{bb} + \beta_{pp} + 2\beta_{bp})(b/y)(\ln y) - (\beta_{pp} + \beta_{bp})(b/y)(\ln p)\}
 \end{aligned}$$

$$\begin{aligned}
 MC_p = \partial C / \partial p &= (C/p) [\partial \ln C / \partial \ln H] \{\partial \ln H / \partial \ln p\} \\
 &= (C/p) [\alpha_h + \alpha_{hh} \ln H + \alpha_{hw} \ln w] \{\beta_p + (1 - \beta_b - \beta_p)(p/y) \\
 &\quad + \beta_{pp} \ln p + \beta_{bp} \ln b - (\beta_{pp} + \beta_{bp})[(\ln p)(p/y) + \ln y] \\
 &\quad + (\beta_{bb} + \beta_{pp} + 2\beta_{bp})(p/y)(\ln y) - (\beta_{bb} + \beta_{bp})(p/y)(\ln b)\}
 \end{aligned}$$

$$\begin{aligned}
 MC_f = \partial C / \partial f &= (C/f) [\partial \ln C / \partial \ln H] \{\partial \ln H / \partial \ln f\} \\
 &= (C/f) [\alpha_h + \alpha_{hh} \ln H + \alpha_{hw} \ln w] (f/y)[(\beta_y - \beta_b - \beta_p) \\
 &\quad + \beta_{bb} (\ln y - \ln b) + \beta_{pp} (\ln y - \ln p) + \beta_{bp} (2\ln y - \ln b - \ln p)].
 \end{aligned}$$

CHAPTER 7: WINE DEMAND, PRICE STRATEGY, AND TAX POLICY

A number of states unassociated in the public mind with wine production, such as Washington, Oregon, and Missouri, have in recent decades developed thriving wine industries. Because wine quality and taste differ so greatly by geographic origin and variety, newcomer regions have substantial opportunities to carve out market niches (Meridith). Indeed, wine is a good example of a monopolistically competitive industry: a large number of firms and locales competing to sell generically related but differentiated products. Part of the differentiation inheres in the producing region's climate and soil type, part in annual weather variations, and part in winemaking skill, sales promotion, and pricing. The palette's reaction to wine is sensitive to the foods eaten with it, to the wine's image, and to other subjective factors. Even a small firm or producing area therefore has substantial leeway in price and promotion strategy.

Our purpose is to examine consumer preferences for wines from two alternative locales: that in which the consumer lives, and a neighboring one. Consumer proximity to the producing area is of less interest to us than is the demand impact of area-of-origin itself. Our study focuses on Oregon consumption of West Coast wines, although in its major outlines it is probably fairly representative of other areas of the United States as well. Most wine consumed in Oregon is produced in California, Washington, or Oregon. In 1996, for example, approximately 60% of the value of Oregon purchases were from California, 17% from Oregon, 6% from Washington, and 15% from elsewhere (Oregon Liquor Control Commission, 1997). Because the last category is so heterogeneous, it is ignored in the present work.

Cross-State Competition

The Oregon wine industry had its earliest beginnings 35 years ago. In 1995, 113 wineries in Oregon produced wine valued at \$48 million on the retail shelf. They are primarily varietal rather than jug or generic wines (OLCC, 1997). White varietals, chiefly chardonnay, white riesling, pinot gris, and muller-thurgau, represented 61 % of the value of Oregon wines. Red varietals, principally pinot noirs, represented the remaining 39%. Oregon's best-known and fastest-growing varietal is the pinot noir. Sixty-six percent of Oregon wine is sold in-state, 34 % out of state (Oregon Agricultural Statistics Service, 1997).

Oregon's effort to develop a premium image is clear from the tough standards the industry has imposed on varietal and area-of-origin labelling (OLCC, 1992). A varietal designation is reserved for wines containing at least 90% of the grape variety listed on the label, in contrast to the federal requirement of 75 %.¹ Designation of state or locale of origin is mandatory on all wine labels. One-hundred percent of the grape must come from the areas so indicated, compared to the federal and California requirement of only 75 % (Goux, pp. 40 - 44, 1993).

California's varietal wines remain the reference against which Americans tend to judge the quality of other domestic varietals. Yet Oregon wineries' competition with California and Washington probably is limited by differences in the premium grape varieties the three states produce. Cabernets and merlots, widely believed to have a rather distinct consumer market among the red varietals, are heavily produced in California and Washington and little produced in Oregon. On the other hand Oregon's flagship, the pinot noir, is a relatively minor variety in Washington. All three states do produce roughly similar proportions of chardonnay and white riesling. Yet these leading white varietals are

thought to have less distinctive identities than do the leading individual reds. One would expect aggregate cross-state competition among white wines, therefore, to be greater than among the red wines.

A small wine-producing region such as Oregon can compete with larger, better-known regions by varying either its price structure or quality image, including the consumer niches it establishes in variety and taste. In the present analysis we will take variety and quality image as given and concentrate on price strategy. In particular, we are interested in the relationship between the consumer demand for red wine and for white wine, and between the demand for a wine from one region and that from another region. The central issue, that is, will be the interaction between varietal and regional effects in wine demand, and the use of this interaction in price strategy and tax policy.

Earlier Work

The literature on wine demand gives us little to start from. Most wine demand estimates are contained in larger studies of the demand for alcoholic beverages, in which wine is aggregated into a single commodity. Clements and Johnson (1983), Heien and Pompelli (1989), and Gao, Wailes, and Cramer (1995), for example, examine aggregate demands for beer, wine, and spirits. Their estimates of the own-price elasticity of wine demand huddle in the -0.40 to -0.55 range, implying that a reduction in aggregate wine price of 10% would increase wine demand quantity by only about 5%.² Wine expenditure elasticities, that is wine demand responses to increases in total alcohol expenditure, range from as low as 0.75 in one study to as high as 5.00 in another, partly because of differences in econometric specification. These models are useful for forecasting tax revenues but provide little guidance to the wine trade.

We have found only two examinations of U.S. wine demand itself. Folwell and Baritelle (1978) used 7,000 U.S. household expenditure records to estimate an aggregate demand function for red varietals and for white varietals, each broken down by consumption region. In each function, wine demand was related to the wine's price, to consumer income, and in several cases to the price of a related wine. Own-price elasticities averaged -0.81 for red varietals and -0.64 for white varietals, suggesting somewhat more elastic demands than in the all-alcoholic-beverage studies. Income elasticities hovered around 0.50. Unfortunately, little attention was paid to such interactions as the impact of white wine prices on red wine demands.

In the most complete demand analysis yet, Pompelli and Heien (1991) examined the 1980 white wine consumption behavior of 3,000 U.S. households. Demands for domestic white and imported white wine were each related to the prices of various domestic and imported wines, to household income, and to demographic characteristics such as family size, age, and location. Own-price elasticity of domestic white varietals was -0.85, compared to the average of -0.64 in Folwell and Baritelle. Income elasticities were little more than zero (and indeed statistically nonsignificant), likely because the included demographic factors already accounted for income effects.

A critical issue in wine pricing is the effect of one wine's price on the quantity demanded of another, holding either nominal or real income constant. At first blush, we might think of reds and whites as substitutes for one another, that is, alternative versions of the wine consumption experience. Yet the two wine types go with quite different foods, and increasing numbers of wine consumers drink only white or only red wine. Retail buyers may therefore think of the two wine types as something to be stocked together in order to satisfy their guests disparate tastes, much as they buy salt and pepper. Pompelli

and Heien provide tantalizing, but in the end inconclusive, evidence about whether red wines substitute for or complement white wines. In the eight instances in which the price of a red was related to the demand for a white, the sign was positive three times (implying reds substitute for whites) and negative five times (implying reds complement whites). Yet in no case was the effect statistically significant. We suspect that the nonsignificance, and approximately equal number of positive and negative signs, comes from high correlations among the price variables rather than from an absence of substitute or complement effects in the wine demands themselves.

The Data

In contrast to the household panels in these earlier studies, we use scanner data from the major retail chain stores in Portland, Oregon. Seventy-four percent of the quantity, and 46% of the value, of total Oregon wine sales are intended for off-premise consumption, and most of this off-premise wine is marketed through the major chains (Steve L. Barsby and Associates). Our data provide monthly information on price and quantity of each wine sold, distinguished by state of origin, winery, variety, and container size. Information on approximately 1,200 distinct wine labels was reported each month, representing hundreds of West Coast wineries. The series runs from April 1993 through September 1994.

A Look at the Data

We divided the data into four categories: Oregon reds, Oregon whites, California and Washington reds, and California and Washington whites. In each category and for each month, we summed the wine quantities sold and computed the weighted mean price. The weight used with each price was the associated expenditure taken as a proportion of

total expenditure in the respective category and month. Container sizes other than the standard 750-ml bottle were excluded, since most Oregon wine is sold in this size and since the demand structure for liter and jug wine probably differs from the generally higher-quality wine marketed in standard bottles.

Table 1 shows the means and standard deviations of monthly prices and sale quantities of the four wine categories. (For simplicity, California and Washington wines are referred to in table 1 and below as "California" wines.) On average, Oregon red wines sold in Portland were priced 26% higher than were California reds sold in Portland. Oregon white wines were priced only 6% higher than California whites. Portlanders bought more than six times as much red wine, and three times as much white wine, from California as from Oregon. Forty-seven percent of Portland expenditures on West Coast wines went to California whites, and 30% to California reds; only 17% percent went to Oregon whites and 6% to Oregon reds.

Using Scanner Data

Although scanner data tell us much more than do household panels about the product purchased, they provide no information about customer incomes or demographic characteristics. For this reason, Holdren (1960) argued that demand functions based on scanner data are "retail" rather than consumer demands. They characterize, in other words, nothing more than net consumer responses to price changes and to nonprice inducements such as advertising. However, Capps (1989) has shown under certain circumstances that consumer demand inferences can be drawn from such "retail" functions. Capps used a Houston food chain's weekly scanner records to regress aggregate sale quantities of various meat cuts against their prices, the chain's meat advertising space in local newspapers, and seasonal and proximity-to-payday dummy variables. Advertising data were collected

separately from scanner data. Capps argued that consumer income needn't be included in the analysis, because most of the chain's patrons are from high income brackets. Using this reasoning, his specification would indeed be consistent with a standard consumer demand model. Brooker, Eastwood, and Gray (1994) took a similar approach.³

Our task is at once more difficult and easier than Capps'. His focus on a particular food chain enabled him to assess advertising effects, something we cannot do with data aggregated over numerous retail firms in a metropolitan area. In any event, retail stores do not do a great deal of wine advertising. Capps' single-firm scanner data probably understates a consumer's total demand for the item in question inasmuch as a customer may shop at other chains. We avoid most of this understatement because few Oregon consumers cross state lines to buy wine.⁴

We do exclude the 26% of Oregon wine consumption that takes place in tasting rooms and restaurants. This is an advantage. Consumer behavior likely is more festive and less price-conscious in restaurants and on the tasting room circuit than it is in retail stores, so price elasticities in these places are probably much different as well. Further, it is unlikely that on-premise wine consumption is a very significant substitute for wine purchased in retail stores and consumed at home. Restaurant and tasting room wine demand is therefore best reserved for a separate study. In doing so, we exclude much of the higher-end product (upwards of \$10 a bottle), which among Oregon wines is disproportionately pinor noir.

Wine Demand Estimates

The Rotterdam system was chosen to estimate the demand for each of the four wine categories described above (Deaton and Muellbauer, pp. 67 - 69; Alston and Chalfant). Rationality restrictions from demand theory are easily maintained with this system. In particular, we restrict the sum of the four products' share-weighted income elasticities to be unity (Engel aggregation), the share-weighted sum of each product's utility-compensated price elasticities to be zero (Cournot aggregation), and the share-weighted utility-compensated elasticities to be symmetric (implying, with Cournot aggregation, zero homogeneity in prices).⁵ Use of an expenditure variable in these equations, representing total expenditures on all four wine categories in a given month, assumes retail-level wine demands are separable from the demands for other products. Scanner data requires such an assumption. It is, nevertheless, not too egregious considering the special role that wine plays in many households. Seemingly Unrelated Regression (SUR) estimates were computed with SAS Version 6.10.

We initially tested the endogeneity of the expenditure variable by regressing it, as an auxiliary equation in the SUR system, against a number of instruments, including Oregon monthly employment (LaFrance, 1991; Capps et al., 1994). None of the auxiliary equations were significant and the exogenous specification was therefore retained. We also tested and rejected the hypothesis that wine demands increase during the winter holiday season.

Uncompensated Demands

Table 2 gives the Marshallian price and expenditure elasticities estimated after removal of the seasonal dummy variable. Expenditure elasticities of California wines (bottom of the table) are slightly higher than those of Oregon wines, implying California wines have a somewhat higher quality image in Portland than do Oregon wines. Yet none of these propensities to allocate a dollar of wine expenditure are very far from unity. Now observe the price-quantity matrix at the top of the table. Demands for both Oregon and California reds are own-price inelastic (weighted average -0.25), a result that is unsurprising given our earlier remarks about the specialized appeal of many red varietals. By contrast, demands for both Oregon and California whites are elastic (weighted average -1.24), consistent with the less discriminating preferences that experts say most consumers have for white wines. Whites are consumed at cooler temperatures than reds, so taste differences between Oregon and California whites would be more subdued than between the reds. Our red wine own-price elasticities are below those in Folwell and Baritelle, but our white wine elasticities are higher than both Folwell and Baritelle's and Pompelli and Heien's.

Perhaps more intriguing in table 2 is an opportunity to examine the question, unresolved in Pompelli and Heien, of the demand interactions between red and white wines. The most unambiguous way to do so is to observe the cross-price elasticities between red and white Oregon wines (top left 2×2 matrix), then between red and white California wines (bottom right 2×2 matrix). The answer in both cases is that reds and whites appear to be complements: all four within-state cross-price elasticities are negative. The interactions are nonsymmetric. Reducing the price of Oregon white wines by 1% increases the demand for Oregon reds by 1.9%, while reducing the price of Oregon reds 1%

increases the demand for Oregon whites by only 0.6%. This asymmetry is a natural result of white wine's higher share of the wine consumer's dollar.

On the other hand, a wine from one state is a Marshallian substitute for the same-colored wine from the other state. This substitution is quite strong if the price change is initiated in California. When California producers cut red (white) prices 1%, the demand for Oregon reds (whites) falls nearly 2%. Thus, Oregon producers cannot depart very far from price changes initiated in California. Unfortunately for Oregon price leadership, the substitution is weak when the price change is initiated in Oregon: the percentage impact of a 1% Oregon price change on the demand for a California wine is only 0.37 among reds and 0.65 among whites. Some of the superiority of California's price leadership potential comes from its superior market share, although part may arise from its superior quality image. In any event, the asymmetry underscores a new wine industry's strategic limits even in the confines of its own state, where customers arguably are well-disposed to local producers.

Finally, consider the reverse diagonal entries (-0.35, -0.76, -0.44, -0.06) in table 2, representing the effects of a given price on the demand for a wine of different color and region. Here the consumer compares, say, a white wine from California with a red from Oregon, so the entries combine what we found above to be a negative (complementary) cross-color effect with a positive (substitutive) cross-state effect. The uniformly negative signs on the reverse diagonal suggest that cross-color complementarity is strong enough to overwhelm cross-state substitution, although the net magnitudes are not large.⁶

Price Strategies

A complete system of demand equations serves as an excellent basis for a payoff matrix of pricing strategies. In table 3, we show the proportional and total monthly revenue changes that would occur at retail given alternative combinations of changes in Oregon red and white wine prices, assuming California prices remain fixed. The no-change scenario in the upper-left cell represents revenues accruing at sample-mean prices and quantities. Figures in the lower-left and upper-right cells, in which only one price changes, are computed from standard formulae for a revenue change as a function of a demand elasticity. Those in the lower-right cell, where both prices change, are derived from the full differential versions of such formulae, which employ the sums of the elasticities in the relevant columns of table 2. Strategies involving price increases were clearly inoptimal and are not shown.

Table 3 makes clear that reducing white wine prices would boost white wine revenue whether or not red wine prices are changed. The gain is greater if red wine prices are reduced also, since the red-white complementarity in table 2 implies that cutting red wine prices increases the demand for white wine. Complementarity also explains the strong red wine revenue gain when white wine prices fall, especially when red wine prices stay fixed. In contrast, the inelasticity of red wine demand ensures that cutting red wine prices reduces red wine revenues provided white wine prices are held constant. Yet if white wine prices are cut along with red wine ones, red wine revenue actually rises by virtue of the strong complementarity between reds and whites.

It is useful to think of table 3 Taken as the payoff matrix for a noncooperative game between red wine and white wine producers. There is a Prisoner's Dilemma. Red producers observe that, regardless of red prices, white producers maximize revenues by

cutting white prices. White producers observe that, regardless of white prices, red producers maximize revenues by holding red prices fixed. Hence, the upper right cell (reduce white prices, leave red prices unchanged) is the dominant pair of strategies if the two parties behave as competitors. On the other hand, the bottom right cell (reduce both prices) maximizes the sum of the parties' revenue gains and is therefore the strategy they will choose if they cooperate. This story oversimplifies real-world conditions. Most wineries produce both reds and whites. Even if they didn't, they would violate anti-trust law by organizing themselves into the two groups that, strictly speaking, the above game requires.

Nevertheless, the game provides two useful insights. First, larger wineries' price structures typically influence smaller wineries' prices. Thus, wine pricing probably does have an implicitly coordinated element to it, and the thinking that goes into economic games is relevant to this coordination. Second, the wine industry's monopolistically competitive nature is such that even a small firm maintains some strategic independence from its rivals. A winery strives for, and often achieves, a measure of customer loyalty permitting individual latitude in strategic price setting. It is reasonable to think that the preference structures it faces for its individuated products will reflect to some degree the aggregate preference structures shown in tables 2 and 3. To wit, if red and white wines are complementary in the aggregate, one would expect them to be complementary at a typical winery as well. That is, of course, an hypothesis to be tested in future work.

Compensated Demands and Tax Policy

A way of examining the robustness of the complementarity between red and white wines is to ask whether it persists when consumers are compensated for the price changes in question. That is, how much of the complementarity in table 2 is income effect and how much is net complementation? The Hicksian elasticities, in which consumers are assumed to be subsidized as compensation for the income effect of a price increase, are shown in table 4 to answer this question.

All four cross-product terms in table 4 relating the red and white wines of a given state (-1.739, -0.589, -0.234, -0.146) are algebraically larger than their Marshallian counterparts in table 2, as required for normal goods. Yet they all remain negative, implying that red and white wines complement one another even when income effects are ignored. Complementarity is decidedly weaker among California wines (where indeed it is statistically nonsignificant) than it is among Oregon wines. Compensated own-price elasticities in table 4 are, owing to rather moderate expenditure effects, not much lower than the Marshallian own-price elasticities in table 2. Compensated demand for California reds is especially unresponsive to price, another confirmation of the expert opinion that California cabernets and merlots have a specialized market.

Hicksian compensated demands are especially valuable for determining the welfare effects of policy changes. Proposals are perennially before the Oregon legislature, as they likely are in most states, to increase the per-unit tax on table wine. In Oregon, the tax currently stands at \$0.67/gallon in addition to a \$1.07/gallon federal tax. Any tax boost would be applied equally to all wines sold in the state, regardless of origin. Taxes on non-Oregon wines are levied on the firms importing the products into the state; taxes on Oregon wines are levied on the wineries.

Two questions arise about a proposal to boost taxes: how much revenue would the state government earn, and how much welfare would consumers lose? The latter question is answered by finding the equivalent or compensating variation of the tax increase, which is a line integral under the compensated demands from the pre-tax to the post-tax prices. In the line integral, one first finds the amount of money that Oregon red wine consumers would demand as compensation for the price increase induced by the Oregon red wine tax boost, holding the other three prices at pre-tax levels. One then finds the amount of money Oregon white wine consumers would demand as compensation for the price increase induced by the Oregon white wine tax boost, given that the Oregon red wine tax has already been increased, and so on until all four demand compensations are computed. The line integral is the sum of these four successively-price-adjusted compensation demands (Just, Hueth, and Schmitz, pp. 365 - 369).

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We first modelled a tax increase of \$0.67 per gallon (\$0.1327 per 750-ml bottle) on wines of all origins, effectively doubling the present state tax. The equivalent variation of this tax increase, computed using table 4's compensated elasticities in conjunction with mean prices and quantities, is \$471,534 per year assuming full tax pass-through from importer or winery to consumer. This says that Portland consumers would lose an annual equivalent of \$471,534 from the tax boost in the sense that it is the most they would pay to avoid the boost, assuming the boost does not in fact take place. The state's tax revenue gain, in contrast, is determined by multiplying the \$0.67-per-gallon tax increase times the

Marshallian quantities demanded in Portland after the tax. Using demand parameter estimates in table 2, footnote c, the total tax revenue increase would be \$460,956 per year.

In order to be useful for policy purposes, we must rescale these figures to reflect the relative size of our regression sample. The Portland sample represents 12.18% of 1994 Oregon retail wine sales value, and 8.98% of Oregon total (retail and restaurant) wine sales value. Rescaling consumer cost and tax revenue by the former percentage to reflect the non-Portland component of retail store sales is fairly benign, since Portland and non-Portland wine demands probably are quite similar to one another. Rescaling by the latter percentage to include restaurant sales introduces error to the extent that restaurant demands differ from those in retail stores. With this caveat in mind, and using a total rescaling factor of $1/0.0898 = 11.13$, we estimate that a doubling of the state wine tax would cost Oregon consumers \$5,248,173 and raise \$5,130,440 in state tax revenues annually.

The \$117,733 difference between equivalent variation and tax revenue is the deadweight loss of the tax boost, namely the amount by which consumer cost exceeds the state's gain (Mas-Colell, Whinston, and Greene, pp. 84 - 87). A deadweight loss of \$117,733 represents only 2.3% of the tax revenue enhancement, a great deal lower than the 38.0% that Heien and Pompelli predicted for a nationwide tax on alcohol.⁷ Deadweight loss is low here because the compensated demands in table 4 are own-price inelastic, implying that a tax boost would affect wine consumption only modestly provided consumers are compensated for the boost. To test the sensitivity of these results to the size of tax hike, we next assumed a state tax increase of \$2.34 per gallon, effectively tripling the present rate. Annual consumer cost of this higher boost would be \$10,299,166 and annual tax revenue gain \$10,046,941. Annual deadweight loss would be just \$252,225, again only about 2.5% of tax revenue. We shouldn't take quite so literally the prediction that a

doubled tax rate would double tax revenues. Any tax increase would induce some substitution away from wines and into competing beverages. However, Heien and Pompelli, Clements and Johnson, and others have shown that such substitution is very modest.

Summary

Consistent with our expectations, we find the demands for red wines to be inelastic and the demands for whites elastic. Reds and whites complement one another even in the absence of income compensation. Yet red wines (and white wines) from two different regions substitute for each other, particularly if the price change is initiated in the larger, more prestigious production region. Oregon wine prices appear to be too high to maximize producer revenues: white wines because their demands are elastic, and red wines because they are complements for white wines. On the other hand, deadweight losses from any tax increase would be modest, largely because compensated own-price elasticities are modest also.

An important qualification of these results is our assumption that the demand for retail store wines is weakly separable from the demand for all other goods. The implication of such an assumption is that consumers first decide how much to spend on retail wines in total, then allocate those expenditures among specific wines without further regard to the prices of non-retail-wine goods. Had the data permitted, it might have been preferable to apply the separability assumption to a category of expenditures wider than retail wines. As we have argued, however, any resulting bias is likely small, given the unique dietary and social role of wine in most households. Most importantly, this study provides a rare look at a disaggregated wine demand system, permitting a close examination of the interactions between wine type and area of origin.

Table 1. Portland Retail Prices, Quantities, Expenditures, and Expenditure Shares on Oregon and California Wines: Monthly Aggregate Means and Standard Deviations, April 1993 - September 1994.

	Mean	Standard Deviation
<i>Prices (\$/750-ml bottle)</i>		
Oregon Red	7.41	0.22
Oregon White	5.71	0.11
California Red ^a	5.87	0.13
California White	5.37	0.11
<i>Quantities (750-ml bottles/month)</i>		
Oregon Red	12,996	2,142
Oregon White	49,753	7,876
California Red	84,589	11,384
California White	148,782	18,182
<i>Total Expenditure (\$/month)</i>	1,675,676	204,898

^a The term "California" in this and subsequent tables refers to wines from both California and Washington. Approximately 90% of California and Washington wines consumed in Oregon are from California.

Table 2. Marshallian Retail Demand and Expenditure Elasticities, Portland Wine Consumption, April 1993 - September 1994.^{a, b}

		<i>Quantities Demanded (i)</i>			
		Oregon Red	Oregon White	California Red	California White
<i>Prices (j)</i>	Oregon Red	-0.517	-0.642	0.373	-0.060
	Oregon White	-1.866	-1.413	-0.437	0.650
	California Red	1.983	-0.758	-0.193	-0.461
	California White	-0.351	1.902	-0.681	-1.190
<i>Average Expenditures Shares (w_i)</i>		0.057	0.169	0.297	0.476
<i>Expenditure Elasticities (η_i)</i>		0.751	0.911	0.938	1.061

^a The Rotterdam model is $w_i \ln q_i = b_i \ln \bar{x} + \sum_j c_{ij} \ln p_j$, where $i = 1, \dots, 4$ indexes the good, $j = 1, \dots, 4$ indexes the price, w_i is expenditure share, q_i is consumption, $\bar{x}$ is real (price-deflated) expenditure, p_j is price, and $b_i = w_i \eta_i$ and c_{ij} are estimated parameters (Deaton and Muellbauer, pp. 67-70). Marshallian demand elasticities in this table were calculated as $e_{ij} = e_{ij}^* - w_j \eta_i$, where e_{ij}^* is the corresponding Hicksian compensated demand elasticity (see table 4), w_j is expenditure share at sample means, and η_i is expenditure elasticity.

^b System weighted mean square error was 1.1724 with 58 degrees of freedom. System weighted R^2 was 0.962.

Table 3. Monthly Portland Retail Revenue Changes Given Alternative Oregon Wine Pricing Strategies.^a

		White Wines	
		<i>Leave White Wine Prices Unchanged</i>	<i>Reduce White Wine Prices 10%</i>
Red Wines	<i>Leave Red Wine Prices Unchanged</i>		Whites: + 4.0% (\$11,362) Reds: +18.7% (\$18,014) Total: +7.7% (\$29,376)
	<i>Reduce Red Wine Prices 10%</i>	Whites: +6.4% (\$18,180) Reds: -4.9% (-\$4,720) Total: +3.5% (\$13,460)	Whites: +10.3% (\$29,258) Reds: +13.6% (\$13,102) Total: +11.1% (\$42,360)

^a Revenue changes are expressed relative to sample mean prices and quantities.

Table 4. Hicksian Compensated Retail Demand Elasticities, Portland Wine Consumption, April 1993 - September 1994.^{a, b}

		<i>Quantities Demanded (i)</i>			
		Oregon	Oregon	California	California
		Red	White	Red	White
<i>Prices (j)</i>	Oregon Red	-0.474 (-1.26)	-0.589 (-2.76)	0.426 (2.83)	0.002 (-0.01)
	Oregon White	-1.739 (-2.76)	-1.259 (-1.87)	-0.278 (-0.72)	0.830 (4.07)
	California Red	2.206 (2.83)	-0.487 (-0.72)	0.086 (-0.14)	-0.146 (-0.54)
	California White	0.007 (-0.01)	2.335 (4.07)	-0.234 (-0.54)	-0.685 (-2.30)

^a Hicksian compensated demand elasticities were calculated as $e_{ij}^* = c_{ij} / w_i$, where c_{ij} is as defined in table 2 and w_i is expenditure share at sample means (Deaton and Muellbauer, p. 68).

^b t-values are shown in parentheses.

Footnotes

1. The exception is that wines sold as cabernet sauvignon need contain only 75% of the cabernet grape.
2. Uri's (1986) study places the own-price elasticity somewhat higher, at -0.87.
3. See also Cotterill's (1994) summary of the use of scanner data in demand analysis.
4. Both California and Washington have a sales tax, while Oregon does not.
5. Alston and Chalfant report that consumer rationality restrictions were easier to confirm with the Rotterdam than with the difference form of the AIDS model.
6. Uncompensated elasticities in table 2 were derived algebraically from the compensated elasticities (table 4) and thus are shown without standard errors. However, the low t-values on the upsloping diagonal of table 4 suggest that the corresponding table 2 entries are nonsignificantly different from zero.
7. Heien and Pompelli used compensating rather than equivalent variation as the consumer cost measure.

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CHAPTER 8: NONPARAMETRIC ANALYSIS OF POOLED PRODUCTION DATA

1. Introduction

In this chapter we develop a nonparametric methodology to study producers behavior and production technology with pooled data. This method is applied (in chapters 9 and 10) to study technological changes and farmer's response to component pricing.

Empirical analyses of production technology and producer behavior are often based on a sample consisting of repeated observations on a cross section of firms. That is, the data constitute a panel, describing the choices of a few producers, each over several time periods. Some authors (*e.g.* Mundlak 1978) have proposed traditional parametric methodologies for analyzing such pooled data. The question raised in this paper is whether panel data is useful for nonparametric analysis. By employing a method that resembles the revealed-preferences approach to consumer theory, we show that the answer is yes.

Nonparametric methods are useful for testing the consistency of observed data with a particular behavioral rule and certain technological restrictions, with no need for maintained assumptions about the form of the production function. In comparison to traditional econometric analysis, this is an important advantage. Indeed, nonparametric approaches have gained popularity in production analyses over the last decade. These approaches have been used by: Fawson and Shumway (1988) and Chavas and Cox (1988) to study aggregate agricultural data in the US; Chavas and Cox (1989) to compare aggregate American and Japanese industrial data; and Lim and Shumway (1992) to study scale economies. Other authors, such as Tauer (1995) and Featherstone, Moghnieh and Goodwin (1995) have studied, nonparametrically, firm-level panel data.

The main drawback of nonparametric methods is that, in principle, they require stability of the production technology and behavioral rules over all the observations. Whereas behavioral rules, such as cost minimization or profit maximization, can be expected to be stationary, the underlying technology may vary both over time and across producers. Recognizing this deficiency, Chavas and Cox (1988) extended the work of Hanoch and Rothschild (1972) and Varian (1984) to account for technological changes over time. They

did not consider, however, cross-sectional technological variations. The approach taken by both Tauer (1995) and Featherstone, Moghnieh and Goodwin (1995) was to analyze each production unit separately. This practice overcomes the problem of technological variations across firms, but implies that the available information is not fully exploited, leading to reduced test power.

The essence of this paper is to propose a production model which is general enough to model real-world pooled production data, yet sufficiently restricted to allow meaningful nonparametric analysis. We show that as long as the technological variations are not too wild, pooled data can be used for a nonparametric test based on a revealed technological superiority approach. The proposed method is intuitive and easy to implement via simple pair-wise comparisons.

2. Revealed Technological Superiority Approach to Producer Theory

In analyses of consumer behavior, one does not observe the consumer's objective function – his utility. However the budget constraint is observable, which suffices to test whether a given data set is consistent with constrained utility maximization. For this purpose, Varian (1982) proposed the generalized axiom of revealed preferences (GARP). In analyses of producer behavior, the value of the producer's objective function – his profit – is observable, but the technological constraint – the production set – is not. Moreover, technological variations across production units and over time mean that the production set varies between observations. Below we show that in such cases a procedure that resembles GARP can be employed to nonparametrically test producer behavior. In the context of production analyses, a more meaningful name for GARP would be the “generalized axiom of revealed technological superiority” (GARTS). This axiom adds to the weak axioms of profit maximization, extending the use of nonparametric analyses to pooled data.

We begin the formal analysis by describing the structure of typical panel data available to researchers and by proposing a candidate production model to rationalize these data. The data set consists of $N \cdot T$ (hereafter NT) observations $y^{1,1}, \dots, y^{N,T}$ regarding the actual netput choices made by N competitive producers, each over T time periods. Each observation corresponds to a set of market conditions, given by the vector of netput prices:

$p^{i,t} \in \mathcal{R}_+^n$, and technological-environmental conditions given by a vector $\tau^{i,t} \in \mathcal{R}^m$. It is assumed that $\forall i, t$, such that $i \in \{1, \dots, N\}$ and $t \in \{1, \dots, T\}$, both $p^{i,t}$ and $\tau^{i,t}$ are known to the producer, but only $p^{i,t}$ is known to the researcher.

The production technology is represented by the production set $Y(\tau^{i,t})$. Since, the technological and environmental conditions may vary from one observation to the next, each observation is characterized by its own production set. That is, the NT observations correspond to a family of production sets: $\mathcal{Y} = \{Y^1, \dots, Y^{NT}\}$.

In the general case, where no additional assumptions are made concerning the family $\mathcal{Y}$, the data are of no use for testing behavioral rules or technological restrictions. For example, any data set could be, trivially, rationalized as consistent with profit maximization, by the family $\mathcal{Y} \equiv \{\{y^1\}, \dots, \{y^{NT}\}\}$. We propose to set a restriction on the family $\mathcal{Y}$ that eliminates the possibility of such a trivial rationalization, yet maintains its capacity to represent technological variations. The proposed restriction amounts to the assumption that the underlying technologies are rankable, in the following sense.

Definition 1: Rankable Technological Variations (RTV) – *A family of production sets $\mathcal{Y}$ exhibits RTV if and only if its members can be sorted into a nested family such that $Y^1 \subseteq Y^2 \subseteq Y^3 \dots \subseteq Y^{NT}$.*

Thus, each production set is either contained within or contains any other production set. This structure accounts for neutral (Hicks) technological variation over time and across firms. However, it also allows for many types of nonneutral technological variations. Below, the technologies associated with all the NT observations are assumed to be rankable.

Before turning to the test procedure, we need to introduce a few concepts of revealed technological superiority, and formally define GARTS. These concepts are based on the ideas presented by Varian (1983) in the context of a revealed preferences approach to consumer theory.

When we observe $p^j y^j < p^j y^i$, we say that the technology Y^i was directly revealed superior to the technology Y^j ($Y^i R^d Y^j$), for, under profit maximization, had y^i been feasible under the technology Y^j , it would have been chosen. When technological superiority is revealed through a third party, Y^k , we omit the word “directly” and denote this case by: $Y^i R Y^j$. In both cases the relation $Y^j \subseteq Y^i$ holds.

Definition 2: GARTS – $Y^i R Y^j$ implies $p^i y^i \geq p^i y^j$.

3. Rationalizing Pooled Data with Profit Maximization

In this section we show that if the technologies underlying the observations are rankable, GARTS facilitates testing whether the observed data are consistent with a certain optimizing behavior. We elaborate upon the case of profit maximization behavior. Other cases are briefly discussed in the concluding section.

Before turning to the procedure itself, we formally define the optimization behavior and consistency of the data with this behavior.

Definition 3: Rationalizing Pooled Data with Profit Maximization – *A family of production sets $\mathcal{Y}$ p -rationalizes observed producer behavior if $p^i y^i \geq p^i y \quad \forall y \in Y^i$.*

The following Theorem sets the theoretical basis for the test.

Theorem 1: *Consider a set of observations $y^1, \dots, y^{NT}$, corresponding to market conditions given by $p^1, \dots, p^{NT}$. The following statements are equivalent: (1) There exists a nested family of production sets that p -rationalizes the data. (2) The data satisfy GARTS. (3) There exists a nested family of closed, convex, negatively monotonic production sets that rationalizes the data.*

Proof: (1) $\Rightarrow$ (2)

Maintaining (1), showing GARTS is the same as showing that $p^i y^i < p^i y^j$ implies $Y^j \not\subseteq Y^i$. Suppose that this is not the case, so $p^i y^i < p^i y^j$ and $Y^j \subseteq Y^i$. This would mean that y^j was feasible at the time and place, at which the choice y^i was made, contradicting profit maximization, and thus violating (1).

(2) $\Rightarrow$ (3)

We now have to show that there is a nested family of “nice” production sets that p -rationalize the data. The proof is constructive, the first step being to sort the data into

an $L \leq NT$ ordered family of equivalence sets, $\phi^1, \dots, \phi^L$ such that

$$y^i, y^j \in \phi^l \Leftrightarrow p^i y^i \geq p^i y^j \text{ and } p^j y^j \geq p^j y^i, l \in \{1, \dots, L\}$$

and

$$y^j \in \phi^{l+1} \Leftrightarrow \exists y^i \in \phi^l, \text{ such that } p^i y^j > p^i y^i.$$

Since the data passes GARTS this construction is well defined and any netput vector belongs to one and only one of the ϕ^l .

Now, let $\phi^s \ni y^i$ and define the i th observation production set as

$$Y^i \equiv \text{com}^-\{\phi^1, \dots, \phi^s\}.$$

As needed, the above construction implies that $\forall i \in \{1, \dots, NT\}$ $y^i \in Y^i$, namely, y^i is feasible under Y^i . Furthermore, the family $\mathcal{Y}$ exhibits the required nestedness and each of the production sets is closed, convex and negatively monotonic. It is now left to show that the above family p-rationalizes the data.

We must show that $\forall y \in Y^i$ $p^i y \leq p^i y^i$, $\forall i \in \{1, \dots, NT\}$. Let n^i indicates the number of vertices (no. of netputs from

which Y^i was formed) in Y^i and note that any $y \in Y^i$ can be expressed as: $y = \sum_{j=1}^{n^i} t^j (y^j - e^j)$, where $y^j \in Y^i$, $e^j > 0$, $t^j > 0$, and $\sum t^j = 1$. By construction, $p^i y^j \leq p^i y^i \forall y^j \in Y^i$, thus it follows that $p^i t^j (y^j - e^j) \leq t^j p^i y^i$. Now, sum over j from 1 to n^i to get the result.

$$(3) \Rightarrow (1)$$

Trivial, since (3) is stronger. ■

4. Interpretations, Applications, and Extensions

According to this presentation, the consequence of applying GARTS to panel data is binary: either the data pass the test or they don't. The former indicates that the observed data could have been generated by profit maximization subject to RTV. Thus, maintaining profit maximization allows construction of the underlying technology and maintaining rankable varying technology allows testing for profit-maximizing behavior. Failing GARTS means that profit-maximizing behavior, RTV or both are violated.

In many empirical applications the data are subject to measurement errors and thus may incorrectly violate GARTS. Several attempts have been made to overcome this deficiency: Varian (1985, 1990) and Tsur (1989) suggested comparing data variability to the minimal size of perturbation required to make the data pass the test. The approach taken by Hanoch and Rothschild (1972), however, is simpler and still appealing. In our terms, they suggested declaring technical superiority only if the alternative profit is greater than the realized profit by, say, five or ten percent. Passing the test under such conditions could also be related to almost maximizing behavior.¹

Theorem (1) is useful for several classes of applications. The first class includes tests of a variety of technological restrictions, based on pooled data. An example is the commonly assumed restriction of constant return to scale (CRS) technology. This assumption means that the production set is a cone. To test pooled data for CRS, one only needs to add the requirement that the profit vanishes for all the observations to condition (2) of Theorem (1).

In a second class of applications, Theorem (1) can be employed for comparisons of technology between production units and years. For example, consider a test for monotonic technological advances over the years. To pursue this, one can add to condition (2) the requirement that no production unit is found for which the technology of a certain year is revealed superior to the technology that corresponds to a later year.

Finally, Theorem (1) is useful for a preliminary analysis, prior to traditional econometric analysis. We have already mentioned that it can be employed to examine various assumptions concerning the technology, and hence assists in choosing an appropriate

¹ Equally important but treated to a much lesser extent is the power problem: data may pass a nonparametric test such as GARTS although it has been generated by non-optimizing behavior.

function to represent the technology. In addition, the theorem can be applied to test various hypotheses which are unique to empirical analyses of pooled data. For example, to account for technological variations in pooled data, researchers often include so-called dummy variables in the regression model to represent separable year and firm effects. A prior nonparametric procedure to test whether this practice is sound could be proceed as follows: Condition (2) of Theorem (1) is applied with the additional requirements that if a technology of year x is revealed superior to that of year y at some particular firm, the reverse relationship is not allowed at any other firm. Moreover, if the technology of firm a is revealed superior to that of firm b at some particular year, the reverse relationship is not permitted in any other year.

This paper can be extended in several directions. First, almost trivially, one can repeat the analysis with a production model based on a production function, rather than a production set. Second, tests based on other behavioral rules, such as cost minimization, can be constructed without conceptual difficulties. To pursue this, the construct of the production set needs to be replaced by an input requirement set. The assumption of a nested family of production sets can be substituted for by assuming that the unionization of any pair of input requirement sets is contained in at least one of them.

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CHAPTER 9: SIMPLE NONPARAMETRIC TEST OF TECHNOLOGICAL CHANGE: THEORY AND APPLICATION TO U.S. AGRICULTURE

1. Introduction

Nonparametric analyses of production data are aimed at testing the consistency of observed behavior with a particular optimizing rule and certain technological restrictions, with no need for maintained assumptions about the form of the production function. These methods have gained special popularity in analyzing technological changes in general, and in the agricultural sector in particular (*e.g.*, Fawson and Shumway (1988); Chavas and Cox (1988, 1990); Tauer 1995; Featherstone *et al.* 1995). Further contributions utilizing nonparametric methods for measuring and explaining productivity and technical change in agriculture include work by Cox and Chavas (1990), and by Chavas and Cox (1992, 1994).

Two main nonparametric approaches for testing technological changes have been proposed in the literature. The first was formulated by Chavas and Cox (1988, 1990) who derived conditions for testing technological changes jointly with profit maximization and cost minimization. The conditions account for both neutral and non-neutral as well as monotonic and non-monotonic technological changes, and can be verified by linear programming. The tests were applied by the above-mentioned authors to study technological changes in the aggregate technology of U.S. agriculture (Chavas and Cox 1988), and to compare technological progress in the American and Japanese industrial sectors (Chavas and Cox 1990). Recently, Chalfant and Zhang (1997) have shown that the associated quantitative indices measuring technological changes may not be invariant to changes in the measurement units.

Fawson and Shumway (1988) proposed an alternative approach, employing a variant of the weak axiom of profit maximization (Varian (1984)) to test the joint hypothesis of profit

maximization and monotonic technological progress. Their test condition is intuitive, and may be verified through simple binary comparisons. However, it does not account for non-monotonic technical changes, and does not distinguish between neutral and non-neutral technological changes. Fawson and Shumway applied their approach to study monotonic progress in the aggregate technologies of various subregions of the U.S. agriculture; their approach was also applied by Featherstone, Moghnieh and Goodwin (1995) to investigate progress among micro-level farm technologies.

This paper suggests new alternative nonparametric procedures for testing for specific structures of technological changes under profit maximization and cost minimization.¹ To this end, we exploit a few of ideas from Bar-Shira and Finkelshtain (1997), who proposed a nonparametric framework for analyzing pooled data, to extend and formalize the framework proposed by Fawson and Shumway and bridge it with the Chavas and Cox's methodology. The proposed procedures have a twofold benefit. Firstly, they are simpler to apply than the tests by Chavas and Cox as they requires only binary comparisons rather than solving linear programs. Secondly, they bring descriptive insight and broaden the interpretation of technological changes. The generalization of Fawson and Shumway include: 1) maintaining cost minimization, rather than profit maximization, as the maintained behavioral rule; 2) consideration of both neutral and non-neutral technological progress; 3) testing for both monotonic and non-monotonic technological changes.

For the purpose of illustration, we chose the same U.S. aggregate agriculture data used by Chavas and Cox (1988). It is therefore not surprising that, in general, our findings are consistent with theirs. Our analysis, in addition, revealed a similarity between the ranks of the technologies and the Tornqvist-Theil measures of Total Factor Productivity (TFP).

The plan of this paper is as follows. After set-up and introduction of some notations, section 3 defines and analyzes the case of rankable technological changes. Section 4 deals with monotone technological progress and section 5 with neutral technological change. Sections 6 explains how to characterize the type of technological change via series of tests.

¹ For consistency of data with fairly general optimization hypothesis under any finite number of constraints, see Chavas and Cox (1993).

Section 7 illustrates the methodology via application of the tests to U.S. agricultural data. The paper ends with final remarks summarizing the main findings.

2. Preliminaries and Notations

The data available to the researcher are T observations regarding the actual netput choices made by a competitive producer at different points in time. The netput vector at time t is denoted by $y^t \equiv (z^t, -x^t) \in \mathcal{R}^n \forall t \in \mathcal{T} \equiv \{1, \dots, T\}$, where z^t and x^t are the output and input vectors. The corresponding market conditions are given by a vector of netput prices $-p^t \equiv (q^t, w^t) \in \mathcal{R}_+^n \forall t \in \mathcal{T}$.

Each observation corresponds to a set of technological-environmental conditions given by a vector $\eta^t \in \mathcal{R}^m \quad t \in \mathcal{T}$. It is assumed that $\forall t \in \mathcal{T}$, both p^t and η^t are known to the producer, but only p^t is observable by the researcher. The production technology is represented either by the *Production Set* (PS) $Y(\eta^t)$ or by the *Input Requirement Set* (IRS) $V(\eta^t, z^t)$.

Since we allow for variations of the technological conditions from one observation to the next, each observation is characterized by its own PS or IRS. That is, the T observations correspond to a family of technologies: either $\mathcal{Y} = \{Y^1, \dots, Y^T\}$ or $\mathcal{V} = \{V^1, \dots, V^T\}$. It is worthwhile to note that each member V^t is itself a nested family of IRS corresponding to different levels of output.

3. Rankable Technological Variation

Technological change is a shift in the production set. Such a shift can take various forms and the essence of nonparametric analysis of technological changes is to identify their specific structure. It should be emphasized that if no structure is imposed on the technology shifts and thus on the technical change, then any data set can be rationalized as consistent with profit maximization or cost minimization and some family of technologies. For example, any data are consistent with profit maximization under the degenerate family of technologies $\mathcal{Y} \equiv \{\{y^1\}, \dots, \{y^T\}\}$ (all production sets are singletons with the actual netput as the unique production plan).

We, therefore, begin by imposing a very general structure of technological change, which eliminates such a trivial rationalization, but allows hypotheses testing. It amounts to the assumption that the family $\mathcal{Y}$ is an ordered family, *i.e.* the technologies associated with the various periods are different, but rankable, and therefore can be ordered from the least to the most advanced. Next, the formal definition is presented.

Definition 1: Rankable Technological Variation (RTV)² – *A family of technologies, $\mathcal{Y}$, exhibits RTV if and only if $\forall t, t' \in \mathcal{T}$, either $Y^t \subseteq Y^{t'}$, or $Y^{t'} \subseteq Y^t$.*

Thus, the relation $\subseteq$ is complete over the family $\mathcal{Y}$, *i.e.* any pair of technologies in $\mathcal{Y}$ are rankable. The completeness and the transitivity of the relation $\subseteq$ over the family $\mathcal{Y}$ imply that the technologies associated with the various years form an ordered family, so that $Y^{i_1} \subseteq Y^{i_2} \subseteq Y^{i_3} \dots \subseteq Y^{i_T}$, where i_1 and i_T denote the indices of the least and the most advanced technologies, respectively. Almost needless to say, the order does not necessarily correspond to the chronological order. This structure accounts for neutral (Hicks) technological change; however, it also allows for many other types of non-neutral technological changes.

Before continuing with the formal analysis it may be useful to consider a graphical example. Consider the four observations regarding the following netputs: (8,-16), (7,-9), (6,-4), (3, -1), and their respective prices: (1, 0.25), (1, 0.60), (1, 0.80), (1, 1.50). These

² Formally, we use the term “ordered” in conjunction with “family of technologies” and the term “rankable” in conjunction with “technological variation”.

data, their convex monotonic hull, and the corresponding iso-profit lines are all drawn in Figure 1. Since the iso-profit lines in Figure 1 cut through the convex monotonic hull, we conclude that these data are not consistent with profit maximization subject to a common stable technology. However, these data are consistent with profit maximization subject to ordered family of technologies which exhibits RTV. An example of an ordered family of technologies which rationalizes the data with profit maximization is as follows. Observation 1 and 4 are associated with the least advanced technology given by their convex monotonic hull (Figure 2). Figure 3 shows the intermediate technology which could have produced the second observation and given by the convex hull of observations 1, 4 and 2. Observation 3 is associated with the most advanced technology and is given by the convex monotonic hull of all the observation (Figure 4).

To test for RTV jointly with profit maximization, we need to introduce a few concepts of *revealed technological superiority*. They are based on the ideas presented by Varian (1983) in the context of a revealed preferences approach to consumer theory, and by Bar-Shira and Finkelshtain (1997) in the context of pooled production data. As will be shown below, these concepts have different interpretations depending on the underlying optimization.

In analyses of consumer behavior, one does not observe the consumer's objective function – his utility. However, the budget constraint is observable, which suffices to test whether a given data set is consistent with constrained utility maximization. For this purpose, Varian (1982) proposed the generalized axiom of revealed preferences (GARP). In analyses of producer behavior, the value of the producer's objective function – his profit or cost – is observable, but the technological constraint – the production set or input requirement set – is not. Moreover, technological variations over time mean that the production set varies between observations. Below we show that in such cases procedures that resemble GARP can be employed to non-parametrically test for consistency of production data with profit maximization and RTV.

Formally, let $t, t' \in \mathcal{T}$. When we observe $p^t y^t < p^t y^{t'}$ we say that the technology $Y^{t'}$ was directly revealed as superior to that of Y^t ($Y^{t'} R^d Y^t$), for, under profit maximization, had $y^{t'}$ been feasible at year t , it would have been chosen. When technological superiority

is revealed through a third party, $Y^{t''}$, we omit the word “directly” and denote this case by: $Y^{t'} R Y^t$. In both cases the binary relation $Y^t \subseteq Y^{t'}$ holds.

In the context of production analyses, a more meaningful name for GARP would be the “Generalized Axiom of Revealed Technological Superiority” (GARTS). The formal definition is given by:

Definition 2: GARTS – $Y^{t'} R Y^t$ implies $p^t y^t \geq p^t y^{t'}$.

Before turning to the test procedure itself, it remains necessary to clarify the term “Rationalizing,” which simply means that there exists a family of ordered technologies under which profit maximization would have generated the observed data. Formally,

Definition 3: Rationalizing Data with Profit Maximization – A family of production sets $\mathcal{Y}$ p -rationalizes observed producer behavior if $p^t y^t \geq p^t y \quad \forall y \in Y^t$.

Theorem 1 sets the theoretical basis for the test for rankable technological changes under profit maximization. It shows that GARTS facilitates testing the joint hypotheses of profit maximization with rankable technological changes.

Theorem 1: Consider a set of observations $y^1, \dots, y^T$, corresponding to market conditions given by $p^1, \dots, p^T$. The following statements are equivalent: (1) There exists an ordered family of production sets that p -rationalizes the data. (2) The data satisfy GARTS. (3) There exists an ordered family of closed, convex, negatively monotonic production sets that p -rationalizes the data.

Proof: (1) $\Rightarrow$ (2)

Maintaining (1), verifying GARTS is the same as showing that $p^t y^t < p^t y^{t'}$ implies $Y^{t'} \not\subseteq Y^t$. Suppose that this is not the case, so $p^t y^t < p^t y^{t'}$ and $Y^{t'} \subseteq Y^t$. This would mean that $y^{t'}$ was feasible at the time in which the choice y^t was made, contradicting profit maximization, and thus violating (1).

(2) $\Rightarrow$ (3)

We now have to demonstrate that there is a nested family of “nice” production sets that p -rationalize the data. The proof is constructive, the first step being to sort the data into

an $L \leq T$ ordered family of equivalence sets, $\phi^1, \dots, \phi^L$ such that

$$y^t, y^{t'} \in \phi^l \Rightarrow p^t y^t \geq p^t y^{t'} \text{ and } p^{t'} y^{t'} \geq p^{t'} y^t, l \in \{1, \dots, L\}$$

and

$$y^{t'} \in \phi^{l+1} \Rightarrow \exists y^t \in \phi^l, \text{ such that } p^t y^{t'} > p^t y^t.$$

Since the data passes GARTS, this construction is well defined and, any netput vector belongs to one and only one of the ϕ^l .

Now, let $\phi^s \ni y^t$ and define the t^{th} observation production set as

$$Y^t \equiv \text{com}^- \{ \phi^1 \cup \phi^2 \cup \dots \phi^s \}.$$

As required, the above construction implies that $\forall t \in \mathcal{T} \ y^t \in Y^t$, namely, y^t is feasible under Y^t . Furthermore, the family $\mathcal{Y}$ exhibits the required nestedness, and each of the production sets is closed, convex and negatively monotonic. It now remains to prove that the above family p-rationalizes the data.

We must show that $\forall y \in Y^t \ p^t y \leq p^t y^t, \forall t \in \mathcal{T}$. Let n^t indicate the number of members in Y^t , and note that any $y \in Y^t$ can be expressed as: $y = \sum_{\tau=1}^{n^t} \omega^\tau (y^\tau - e^\tau)$, where $y^\tau \in Y^t, e^\tau > 0, \omega^\tau \geq 0$, and $\sum \omega^\tau = 1$. By construction, $p^t y^\tau \leq p^t y^t \forall y^\tau \in Y^t$, it then follows that $\omega^\tau p^t (y^\tau - e^\tau) \leq \omega^\tau p^t y^t$. Now, sum over τ from 1 to n^t to obtain the result.

$$(3) \Rightarrow (1)$$

Trivial, since (3) is stronger. ■

Condition 2 of Theorem 1 facilitates the test. If the data satisfy GARTS (condition 2), then one is assured that there is an ordered family of technologies which rationalizes the observed choice as consistent with profit maximization. In other words, when profit maximization is maintained, condition 2 makes a simple nonparametric test for RTV.

At this point, it is of interest to compare our test to others. If data pass GARTS, then there exist h^t, γ^t which satisfy $h^t - h^s + \gamma^t p^t (y^t - y^s) \geq 0, \forall s, t \in \mathcal{T}$.³ This is a test of weak separability, of all netputs from the technological change, presented by Varian

³ The proof follows from Afriat's theorem as stated in Varian (1982).

(1984 p. 588) and Chavas and Cox (1988, eq. 6, p. 305). It is worth mentioning that if the production technology cannot be represented by some functional form, then GARTS generalizes equation 6 of Chavas and Cox to those cases. But when production technology is representable by some functional form, then both tests constitute necessary and sufficient conditions for profit maximization subject to well-behaved production function, which exhibits weak separation of all netputs from the technological change. The benefit of GARTS is twofold. Firstly, it simplifies the computation, as it requires only pairwise comparisons rather than linear programming.⁴ The higher level of computational complexity associated with the linear programming may become crucial, especially in large problems. Secondly, it brings new economic interpretation to the notion of “weak separability of all netputs from the technical change” implying a nested (ordered) family of production sets which could rationalize the data with profit maximization. It is important to note that this separability does not imply separability of all inputs from the technical change and hence does not imply Hicks neutrality.

4. Monotone Technological Progress

In many empirical studies of time series the prior hypothesis is of monotone technological progress. That is, adverse technological changes are usually rare, and hence it is of interest to test for the more restricted form of technological changes – monotone technological progress. The proposed procedures for testing monotone technological progress rely on the theory developed in the previous section. Intuitively, after verifying GARTS, all that is left to verify is whether the ordered family $\mathcal{Y}$ is chronologically ordered or not. In other words, one only needs to check that the ranking of the technologies is monotonic in time. In the sequel, we formulate two alternative procedures for these tests, one for each of the behavioral conjectures: cost minimization and profit maximization. We begin by the formal definition.

Definition 4: Monotone Technological Progress – *A family of technologies $\mathcal{Y}$ exhibits monotone technological progress if and only if, its members form a chronologically ordered family such that $Y^1 \subseteq Y^2 \subseteq Y^3 \dots \subseteq Y^T$.*

⁴ A computer code verifying GARTS (condition 2) is just 4-line long (Varian (1982, p. 972)).

4.1 Monotone Technological Progress with Profit Maximization

To test for technological progress, one can strengthen condition 2 of Theorem 1. That is, if GARTS holds and $\forall t, t' \in \mathcal{T}, t > t'$ implies $Y^{t'} \subseteq Y^t$ (not $Y^{t'} RY^t$), then technological progress is accepted. Intuitively, the extension to condition 2 assures that the family that rationalizes the data is not simply ordered, but is chronologically ordered.

For practical purposes, however, a modified version of Varian's Weak Axiom of Profit Maximization (WAPM) (Fawson and Shumway 1988; Featherstone et al. 1995) constitutes a simpler nonparametric test for technological progress. The Modified WAPM compares current realized profits with alternative profits associated only with past observed netputs, rather than all observed netputs. Thus, the Modified WAPM accounts for technological progress by excusing violations associated with future netputs, on the grounds that they simply were not currently available. Theorem 2 formalizes these ideas by indicating the equivalence of the Modified WAPM and strengthened GARTS.

Theorem 2: Consider a set of observations $y^1, \dots, y^T$, corresponding to market conditions given by $p^1, \dots, p^T$. The following statements are equivalent: (1) There exists a chronologically-ordered family of production sets that p -rationalizes the data. (2) The data satisfy $\forall t, t' \in \mathcal{T}, t > t'$ implies $p^t y^t \geq p^{t'} y^{t'}$ (Modified WAPM). (3) The data satisfy GARTS and $\forall t, t' \in \mathcal{T} t > t'$ implies $Y^{t'} \subseteq Y^t$ (not $Y^{t'} RY^t$) (4) There exists a chronologically-ordered family of closed, convex, negatively monotonic production sets that p -rationalizes the data.

Proof: (1) $\Rightarrow$ (2)

We will show that (2) is necessary for (1). Maintaining rationalization by an ordered family, $t' > t$ and $p^{t'} y^{t'} < p^t y^t$ imply $Y^{t'} \subset Y^t$ which violates chronological order

(2) $\Rightarrow$ (3)

if $\forall t' > t \in \mathcal{T} p^{t'} y^{t'} \geq p^t y^t$ then $\forall t' > t \in \mathcal{T}$ it is not the case that $Y^{t'} R^d Y^t$, which in turns implies both GARTS and $\forall t' > t \in \mathcal{T}$ it is not the case that $Y^{t'} RY^t$

(3) $\Rightarrow$ (4)

We prove by construction. Let the t^{th} year technology be defined as

$$Y^t \equiv \text{com}^-\{y^1, \dots, y^t\}.$$

The above construction implies that $\forall t \in \mathcal{T} \ y^t \in Y^t$, namely, y^t is feasible under Y^t . Furthermore, the family $\mathcal{Y}$ exhibits chronological order and each of its members is closed, convex and negatively monotonic. It now remains to show that the above family p-rationalizes the data.

We must prove that $\forall y \in Y^t \ p^t y \leq p^t y^t, \ \forall t \in \mathcal{T}$. From the definition of Y^t it follows that any $y \in Y^t$ can be expressed as: $y = \sum_{\tau=1}^t \omega^\tau (y^\tau - e^\tau)$, where $e^\tau > 0$, $\omega^\tau \geq 0$, and $\sum \omega^\tau = 1$; and from (3) it follows that $p^t y^\tau \leq p^t y^t \ \forall t, \tau \in \mathcal{T}$. The latter implies $\omega^\tau p^t (y^\tau - e^\tau) \leq \omega^\tau p^t y^t$. Now, sum over τ from 1 to t and use the former to get the result. (4) $\Rightarrow$ (1)

Trivial, since (4) is stronger. □

If the data satisfy condition 2 of Theorem 2, then one is assured that there is a family of technologies which rationalizes the observed choices as consistent with profit maximization and technological progress.

As profit maximization is a maintained hypothesis in the above tests, failure of the data to satisfy the conditions of Theorems 1 and 2, may be the result of non maximization of profit. This could, mistakenly, lead researchers to reject monotone technological progress as well as RTV in favor of arbitrary wild technological changes. A partial solution to this problem is to formulate analogous tests based on a weaker maintained optimization assumption.

A clear candidate is cost minimization, which is obviously a weaker requirement than profit maximization. For example, firms may choose an efficient input combination to minimize cost, even if they operate in an environment with price and/or multiplicative technological risks, or possess market power. In both situations, the maintained behavioral rule in Theorems 1 and 2 – profit maximization for given prices – would not be fulfilled. Also, if the technology exhibits constant or increasing return to scale, then the profit maximization hypothesis is of no relevance, while cost minimization remains a meaningful behavioral postulate. Therefore, in the next subsection we propose a variation of the above test, which is based on cost minimization rather than profit maximization.

4.2. Monotone Technological Progress with Cost Minimization

To test for monotone technological progress based on cost minimization we employ a modified version of Varian's Weak Axiom of Cost Minimization (WACM). The WACM states that all input bundles capable of producing more output than the bundle x^t must be more expensive than x^t , otherwise cost minimization is violated. The Modified WACM is less restrictive: violation of cost minimization is declared only if there exists an *earlier* input bundle which had produced more output than the current bundle x^t and costs less at the current prices w^t . Violations associated with netputs chosen later than time t are forgiven on the grounds that their underlying technologies were not available at time t . The Modified WACM thus accounts for monotone technological progress.

We turn to formal definitions and a corresponding theorem.

Definition 5: Rationalizing Data with Cost Minimization – *A family of production sets $\mathcal{Y}$ (IRSs $\mathcal{V}$) c-rationalizes observed producer behavior if $w^t x^t \leq w^t x \quad \forall x$, such that $(z^t, -x) \in Y^t \quad (\forall x \in V^t(z^t))$.*

Theorem 3 sets the theoretical basis for the test of monotone technological progress based on cost minimization.

Theorem 3: *Consider a set of observations $(z^1, -x^1), \dots, (z^T, -x^T)$, corresponding to market conditions given by $w^1, \dots, w^T$. The following statements are equivalent: (1) There exists a chronologically-ordered family of production sets that c-rationalizes the data. (2) $\forall t, t' \in \mathcal{T}$, if $z^{t'} > z^t$ and $t > t'$, then $w^t x^t \leq w^t x^{t'}$ (Modified WACM). (3) There exists a chronologically-ordered family of closed, convex, negatively monotonic production sets that c-rationalizes the data.*

Proof: (1) $\Rightarrow$ (2)

Suppose that $z^{t'} > z^t$ and $t > t'$. Since the production sets are chronologically ordered, $Y^{t'} \subseteq Y^t$, implying that $(z^{t'}, -x^{t'}) \in Y^t$. But, since the family of production sets rationalizes the data, it must be the case that $w^t x^t \leq w^t x^{t'}$.

(2) $\Rightarrow$ (3)

We now have to show that there is a chronologically ordered family of “nice” production sets that c-rationalize the data. The proof is constructive.

Define the t^{th} year production set as

$$Y^t \equiv \text{com}^- \{y^1, \dots, y^t\}.$$

As required, the above construction implies that $\forall t \in \mathcal{T} \ y^t \in Y^t$. Furthermore, the family $\mathcal{Y}$ is chronologically ordered and each production set is closed, convex and negatively monotonic. It is now left to show that the above family c-rationalizes the data.

We must demonstrate that $x \in V^t(z^t)$ implies $w^t x \geq w^t x^t$, $\forall t \in \mathcal{T}$. First, recall that the definition of $V^t(z^t)$ is given by:

$$V^t(z^t) \equiv \{x | (z^t, -x) \in Y^t\},$$

which indicates that the convexity and negative monotonicity of Y^t induces the convexity and positive monotonicity of V^t . The latter implies that $\forall x \in V^t(z^t)$ x can be expressed as:

$$x = \sum_{\tau=1}^t \delta^\tau \omega^\tau (x^\tau + e^\tau), \quad (*)$$

where $\omega^\tau > 0$, $e^\tau > 0$, $\sum \omega^\tau = 1$, and

$$\delta^\tau = \begin{cases} 1, & \text{if } z^\tau \geq z^t \\ 0, & \text{if } z^\tau < z^t \end{cases}.$$

Condition 2 ensures that each x^τ for which $\delta^\tau = 1$, satisfies $w^t x^\tau \geq w^t x^t$, which after trivial manipulation yields:

$$\delta^\tau \omega^\tau w^t (x^\tau + e^\tau) \geq \delta^\tau \omega^\tau w^t x^t.$$

Now sum over τ from 1 to t and use $(*)$ to obtain the result.

(3) $\Rightarrow$ (1)

Trivial, since (3) is stronger. □

Again, it is worth emphasizing that condition 2 of the theorem constitutes a practical test for monotone technological progress under cost minimization. By simple binary comparisons, one can examine whether a specific time-series satisfies condition 2. If it does, then one is assured that there is a family of technologies that rationalizes the observed choices as consistent with cost minimization and monotone technological progress.

5. Neutral Technological change

An important question in the context of technological change is the degree of neutrality. That is, researchers are often interested in ascertaining whether the technical rate of substitution between inputs is preserved or modified by the technological change. Technological changes which preserve the technical rate of substitution are regarded in the literature as the most general definition of Hicks neutral changes. A general equivalent definition of Hicks neutrality would be that the technologies associated with the various years rank any pair of input bundles equally. That is, if an input bundle x produces more output than another bundle x' under some technology, then x produces more output than x' under any other technology. We call this property input-rank preserving technological variation (RPTV) and define it formally as follows:

Definition 6: RPTV *A family of technologies $\mathcal{V}$ exhibits RPTV if for all z' , z'' , t' and t'' either $V^{t'}(z') \subseteq V^{t''}(z'')$ or $V^{t''}(z'') \subseteq V^{t'}(z')$.*

Thus, a family of technologies exhibits RPTV if, and only if, all the technologies have identical isoquant maps. However, a certain isoquant may correspond to different output levels under the various technologies. Moreover, RPTV does not necessarily imply RTV and *vice versa*. A family of technologies may exhibit RPTV, but the rankings of the technologies may vary with the output levels, meaning that RTV does not hold. Similarly, a family may exhibit RTV, but isoquant associated with different technologies and output levels may cross, violating RPTV.

To test for Hicks neutral technological changes, one only needs to test for RPTV. The formulation of the test requires the introduction of a suitable axiom – the Generalized Axiom of Revealed Factor Superiority (GARFS).

We begin with the terminology. When we observe $w^t x^t > w^t x^{t'}$, we say that the input bundle x^t was directly revealed superior to the input bundle $x^{t'}$. The only information from such an observation is that under technology t , the input bundle x^t produces more than $x^{t'}$, otherwise cost minimization would have imposed the implementation of the latter. Note that unless $x^{t'}$ is strictly greater than x^t the finding – $w^t x^t > w^t x^{t'}$ – is inconclusive regarding technological superiority. The word “directly” is omitted if factor superiority is inferred by invoking transitivity.

The formal definition of GARFS is as follows

Definition 7: GARFS – $x^t R x^{t'}$ implies $w^t x^{t'} \leq w^{t'} x^t$.

Rationalization in this context is as in Definition 5.

Theorem 4 sets the theoretical basis for the neutrality test, and shows that GARFS facilitates testing whether the observed data are consistent with cost minimizing behavior and RPTV (definition 2).

Theorem 4: Consider a set of observations $x^1, \dots, x^T$, corresponding to market conditions given by $w^1, \dots, w^T$. The following statements are equivalent: (1) There exists a family of IRSs that exhibits RPTV and c-rationalizes the data. (2) The data satisfy GARFS. (3) There exists a family of closed, convex, positively monotonic IRSs that exhibits RPTV and rationalizes the data.

Proof: (1) $\Rightarrow$ (2)

Maintaining (1), showing GARFS is the same as showing that $w^t x^t > w^t x^{t'}$ implies $x^{t'} \notin V^t(z^t)$. Suppose that this is not the case, then $w^t x^t > w^t x^{t'}$ and $x^{t'} \in V^t(z^t)$. This would mean that $x^{t'}$ was feasible at the year at which the choice x^t was made, contradicting cost minimization, and thus violating (1).

(2) $\Rightarrow$ (3)

We now have to show that there is a family of “nice” IRSs that exhibits RPTV and c-rationalizes the data. The proof is constructive, the first step being to sort the data into an $L \leq T$ ordered family of equivalence sets, $\phi^1, \dots, \phi^L$ such that

$$x^t, x^{t'} \in \phi^l \Rightarrow w^t x^t \leq w^t x^{t'} \text{ and } w^{t'} x^{t'} \leq w^{t'} x^t, l \in \{1, \dots, L\}$$

and

$$x^t \in \phi^{l+1} \Rightarrow \exists x^{t'} \in \phi^l, \text{ such that } w^t x^{t'} < w^t x^t.$$

Since the data passes GARFS, this construction is well-defined, and any input vector belongs to one and only one of the ϕ^l .

Now, let $\phi^s \ni x^t$ and define the t^{th} observation IRS as

$$V^t(z^t) \equiv \text{com}^+ \{\phi^1 \cup \phi^2 \cup \dots \phi^s\}.$$

As required, the above construction implies that $\forall t \in \mathcal{T} \ x^t \in V^t$, namely, x^t belongs to V^t . Furthermore, the family $\mathcal{V}$ exhibits RPTV, and each of the IRSs is closed, convex and positively monotonic. It is now left to show that the above family c-rationalizes the data.

We must show that $\forall x \in V^t(z^t) \ w^t x \geq w^t x^t, \ \forall t \in \mathcal{T}$. Let n^t indicate the number of members in $V^t(z^t)$ and note that any $x \in V^t(z^t)$ can be expressed as: $x = \sum_{\tau=1}^{n^t} \omega^\tau (x^\tau + e^\tau)$, where $x^\tau \in V^t(z^t)$, $e^\tau > 0$, $\omega^\tau > 0$, and $\sum \omega^\tau = 1$. By construction, $w^t x^\tau \geq w^t x^t \ \forall x^\tau \in V^t(z^t)$, hence it follows that $\omega^\tau w^t (x^\tau + e^\tau) \geq \omega^\tau w^t x^t$. Now, sum over τ from 1 to n^t to obtain the result.

(3) $\Rightarrow$ (1)

Trivial, since (3) is stronger. ■

As in the previous theorems, condition 2 is the practical one. This condition can be verified by a simple algorithm, and if it holds, one may conclude that the technological change preserves the technical rate of substitution between inputs. In the next section we discuss the possible implementation of various combinations of the above tests. To each combination of failure-success in passing the four axioms associated with the four theorems, we propose an interpretation regarding the technological and behavioral consequences.

6. Integrated Analysis

The four nonparametric tests, corresponding to the four theorems presented above, are combined in a manner that permits reaching clear conclusions regarding the nature of the technological changes. In other words, the data are tested for the four axioms — GARTS, GARFS, Modified WAPM, and Modified WACM simultaneously. The fail-pass pattern then identifies whether the technological change is wild, rankable, neutral, neutral rankable, monotonically progressive, or neutral progressive (not all are identifiable under both behavioral rules).

Before we explain the identification procedure, note that the verification order is not significant and that not all possible fail-pass sequences are feasible, since some of the axioms are necessary for the others. For example, each of the modified axioms is necessary for its respective weak axiom, and the Modified WACM as well as GARTS are necessary for the Modified WAPM, but neither GARTS nor GARFS is necessary for the other. These relationships are summarized in Figure 5. Figure 6 outlines all feasible sequences of fail-pass and the implied nature of the technological variation. We illustrate with 3 examples. 1) The left branch indicates failure of all axioms. If profit maximization or cost minimization is maintained, this branch implies wild technological variations of which the degenerate technology mentioned earlier is a special case. 2) The right branch represents the case in which all axioms pass. This would imply consistency of the data with Hicks-neutral, monotonic technological progress jointly with profit maximizing behavior. 3) Consider the case: passing GARTS, failing Modified WAPM, failing GARFS, passing Modified WACM. Since GARFS failed, Hicks neutrality is excluded. Now look at the pair: passing GARTS and failing Modified WAPM, which supports the conjecture of profit-maximizing behavior subject to rankable technological change. Whereas the pair: failing Modified WAPM and passing Modified WACM supports cost minimizing behavior subject to monotone technological progress. Is this a contradiction? No, since models, other than profit-maximizing behavior subject to rankable technological changes, can generate data which pass GARTS, and models, other than cost minimization subject to technological progress, can generate data which pass Modified WACM. Both, profit maximization subject

to rankable technological changes and cost minimization subject to technological progress, are possible models.

In general, passing GARTS is necessary for RTV jointly with profit maximization. If the data also pass the Modified WAPM, then the technological variations are monotonically progressive. If, in addition, the data pass GARFS, then we know that the monotone technological progress is natural (Hicks). Keeping in mind that the order of the tests is of no importance, the above logic applies to all branches of the tree.

7. Empirical Illustration

The emphasis in this paper has been on the methodological aspects. To exemplify, we chose to study the data used originally by Capalbo and Vo (1988) and later by Chavas and Cox (1988), Cox and Chavas (1990), and Chalfant and Zhang (1997) for the empirical application. The data include aggregate production quantity, ten input quantities and their respective prices during the years 1950-1983. The included inputs are: family labor, hired labor, land, structures, capital, energy, fertilizers, pesticide, other inputs, feed and seed.

We turn now to the primary objective of this paper — to characterize the nature of the technological change. Before testing for the four axioms — GARTS, Modified WAPM, GARFS and Modified WACM, we conducted two pre-tests by checking for the WAPM and the WACM. Both failed, indicating inconsistency with optimizing behavior subject to a stable technology. Next we examined the above four axioms. The test results for GARTS, Modified WAPM, GARFS and Modified WACM are pass, fail, pass, and fail, respectively. This means that the data are consistent with profit-maximizing behavior, subject to Hicks rankable technological variations. However, monotone technological progress is rejected. These conclusion are consistent with those of Chavas and Cox and Chalfant and Zhang.

The analysis thus far indicates that the technologies associated with the various years form an ordered family; however, the order is obviously not chronological. This raises the question: how do the technologies rank? The revealed superiority analysis presented above provides an easy way to the answer. The greater the number of technologies that were revealed superior to a certain technology the lower the rank of that technology.

Figure 7 presents the rank of the 34 technologies, the graph, as expected, is not monotonic but shows significant positive trend. This, in turn, constitutes evidence in favor of non-monotone technological progress. To formally test for non-monotone technological change, we made use of the Spearman correlation coefficient between the rank and year vectors. We found that the this correlation is 0.98808 with p-value of 0.01 percent indicating significant positive correlation between rank and time. Hence we conclude that the hypothesis of non-monotone technological progress cannot be rejected at any reasonable significant level.

Finally we point out a similarity of the rank vector (Figure 7) to the Tornqvist-Theil index of TFP (Figure 8), which is calculated as:

$$\ln \left(\frac{y_t}{y_{t-1}} \right) - 0.5 \sum_{i=1}^{10} \left((s_{i,t} + s_{i,t-1}) \ln \left(\frac{x_t}{x_{t-1}} \right) \right),$$

where, s_{it} is the share of input i in revenue at year t . Comparison of Figures 7 and 8 shows that they are qualitatively identical — a year with higher rank also has a higher measure of TFP and *vice versa*. The Tornqvist measure of TFP has several inherent weaknesses. Firstly, it relies on prices or shares, and is therefore sensitive to changes in return to scale and degree of competitiveness. Secondly, it requires homothetic technology. Thirdly, its accuracy is related to the parametric form of the technology, in this case the translog cost function (Capalbo and Antle, 1988). For these reasons, Chavas and Cox (1994) studied the use of input and output distance functions, relative to inner (primal) and outer (dual) bounds on the reference technology, as a measure of productivity. It seems that the rank vector, like the distance functions, avoids some of the problems associated with the Tornqvist measure but at the same time it lacks the quantitative information contained in the distance functions.

8. Final Remarks

Before summarizing the main contribution of this work, we need to emphasize an additional point which is highly important in empirical applications. The critical regions of non-parametric tests, in contrast to statistical tests, are independent of the significant level. Non-parametric tests, therefore, may reject because of a small deviation which standard statistical tests would consider insignificant. The economic literature has addressed this inherent weakness of non-parametric tests. Hanoch and Rothschild (1972), for example, proposed to declare violation of the WAPM only when there exists an alternative netput which could generate, say, 10 percent more than the actual profit, rather than just greater profit. Varian (1985, 1990), Tsur (1989), and Lim and Shumway (1992) incorporated random measurement error in the data-generating mechanism, and declared violation only when the size of the perturbation required to make the data pass the test was relatively big.

Several new procedures for testing for specific types of technological change under alternative behavioral postulates were presented. Specifically, the four following results were derived: i) GARTS is a necessary and sufficient condition for rankable technological variations under profit maximization; ii) GARFS is a necessary and sufficient condition for Hicks-neutral technological variations under cost minimization; iii) the Modified WAPM is a necessary and sufficient condition for monotone technological progress under profit maximization; iv) the Modified WACM is a necessary and sufficient condition for monotone technological progress under cost minimization. The benefit in the new procedures is twofold. Firstly, they require only pair-wise comparisons, whereas existing procedures for testing for Hicks-neutral and/or non-monotonic technological variation require verifications of linear programs, and are therefore computationally simpler. Secondly, they allow new "revealed preference" interpretation. Finally, the usefulness of the procedures are demonstrated through application to U.S. aggregate agricultural data, showing consistency with previous results.

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Figure 1: Common Stable Technology

Figure 2: Ordered Family — The Least Advanced Technology

Figure 3: Ordered Family — The intermediate Technology

Figure 4: Ordered Family — The Most Advanced Technology

Figure 5: Relations Between the Axioms

Key: $\longrightarrow$ =Implies $\nrightarrow$ =Does not imply

Figure 6: Test-Conclusion Tree

Figure 7: Ranking of Technologies

Figure 8: Tornqvist-Theil Measure of TFP

CHAPTER 10: DO FARMERS RESPOND TO HEDONIC PRICING? A NONPARAMETRIC APPROACH

1. Introduction

Effective performances of marketing channels for agricultural product are often contingent on the success of incentive schemes, provided by component pricing. As such schemes tend to be rather complicated, a key question is whether farmers correctly respond to them. This paper develops a nonparametric procedure to examine this question, under alternative assumptions concerning the underlying farming technology and farmers optimization behavior. When taking into account the possibility of technological heterogeneity across farmers and technological variation over the years, our results are in the affirmative. Farmers seem to correctly respond to component pricing.

Commonly, marketing of agricultural products involve some degree of pooling, where the price received by a farmer is being averaged across various qualities, dates, producers and geographical locations. This implies that along the way of a typical marketing channel, the identity of the individual's producer is lost. An immediate consequent is a potential failure of the price system to fulfill one of its most important functions — information conveyance to producers regarding consumers preferences.

It is well documented in the literature (*e.g.*, Zusman, Perin), that such failures can lead to production of goods with characteristics that do not suite consumers preferences. Under such circumstances the competitive equilibrium need not be Pareto optimal and a loss of welfare might occur. In addition, when farmers are being paid an averaged price, rather than the price that fits their own product quality, sever moral hazard and adverse selection problems may arise. These can result in an overall decrease of the product quality and a reduced trade volume.

In attempt to remove some of these imperfections and to elevate quality, marketing orders, marketing cooperatives and wholesalers of various agricultural goods establish sorting and grading schemes and corresponding quality differential pricing systems. Under these schemes farmers are paid premiums or are charged fines according to a well defined list of characteristics or components of the good. Principal examples are the milk industry, where the components are protein and fat contents (*e.g.*, Perin) and the cotton industry, where premia are paid according to fibers quality (cleanness, color and strength) , length, stickiness and fineness.

The empirical treatments of hedonic prices, thus far, has been concentrating mainly on the demand side. Namely, most studies have been examining various procedures for: 1) the elicitation of consumer preferences for the underlying commodity characteristics; 2) methods for quantifying these preferences in terms of money metric, usually, by the so-called "hedonic prices". There are less empirical evidence concerning the supply side. The question in this context is whether farmers indeed respond to the incentive provided by quality differential prices.

We show in this paper that this hypothesis can be examined by a nonparametric procedure. It is based on several axioms, analog to those of the revealed preference theory, which are easy to test for. In addition to facilitating the above test, the proposed procedure provides a useful revealed-preferences type interpretation to previously derived nonparametric tests of technological change (Chavas and Cox). The test procedure is applied to a sample of Israeli cotton growers who are being paid according to a well defined list of characteristics.

Section 2 presents a production model that accounts for hedonic pricing. The theoretical framework for the nonparametric test procedure is developed in Section 3. Section

4 describes the Israeli cotton industry, discusses some of its principle institutions. Section 5 introduces the data set, and Section 6 summarizes the test results. Section 7 concludes.

2. A Model of Production under Hedonic Pricing

This section introduces a model, capable of explaining cross-sectional time-series production data under hedonic pricing system. It starts with the pricing system and then proceeds to describe some possible behavioral postulates. In the sequel, it outlines the structure of a typical panel data available to researchers and characterizes a families of technology which might have generated them.

The Pricing System

Consider a competitive producer who is paid according to a well defined list of characteristics, $c \in \mathcal{R}^C$. That is, the price per unit of product, x , is given by the function $p(c) : \mathcal{R}^C \rightarrow \mathcal{R}_+$. In some cases, c measures the level of characteristics from a “benchmark” level $\bar{c}$. Accordingly, in these cases, some elements of c may be negative, representing characteristic levels below the “bench-mark” levels.

Often, the function $p(c)$ takes a simple linear form:

$$p(c) = \bar{p} + rc, \tag{1}$$

where $\bar{p} \in \mathcal{R}_+$ is the “benchmark” price, paid for product of the average quality. The elements of $r \in \mathcal{R}_+^C$ are the premia (fines) paid for characteristic levels above (below) the bench mark level. This is not the situation, however, in the Israeli cotton industry, where the function $p(c)$ is defined through a rather complicated tables, given to farmers before each season, detailed in section 4 below as part of the institutional description of the industry.

The producer's profits, denoted by π is

$$\pi = p(c)x - wz, \quad (2)$$

where $z \in \mathcal{R}^Z$ is an input vector and $w \in \mathcal{R}_+^Z$ is the corresponding price vector. The producer is subject to a technological constraint given by the production set $\mathcal{Y}$, containing all feasible "netput" vectors $y = (x, -z, c)$.

Behavioral Postulates

If prices are given, uncertainty is not present, the technology exhibits diminishing returns and growers are not subject to exogenous constraints (such as production quotas), then profit maximization is an attractive behavioral postulate. In the context described above, profit maximization implies that the observed netput level $\tilde{y}$ satisfies

$$p(\tilde{c})\tilde{x} - w\tilde{z} \geq p(c)x - wz \quad \forall (x, -z, c) \in Y. \quad (3)$$

Condition (3) describes complete optimization, when the objective is maximum profit. It implies several behavioral rules, which correspond to partial optimization from the standpoint of (3). Some of these, such as cost minimization, hold even if the conditions that underlying profit maximization fail. For examples, even if farmers face multiplicative risk, constant or increasing return to scale and even if they possess power in the product market, they would still choose an efficient input-characteristics bundle.

An efficient input-characteristic bundle, $(-\tilde{x}, \tilde{c})$, implies that

$$p(\tilde{c})\tilde{x} - w\tilde{z} \geq p(c)\tilde{x} - wz \quad \forall (\tilde{x}, -z, c) \in Y. \quad (4)$$

The distinction between problems (3) and (4) is especially important in the context of our empirical application. We examine cotton production by "kibbutzim" — agricultural

communal settlements. Each industry within a kibbutz (single of kibbutzim), such as cotton growing, is a profit center, with a commune member who runs it. The share of each commune member in the organization profits is determined by a list of criteria, which are not directly related to the member's job performances. However, a member who manages a profitable industry enjoys a considerable social appreciation, which creates an incentive to run an efficient enterprise. The scope of each operation, however, is subject to the decisions of the commune general assembly, and is decided according to a multi-attributes and complicated objective function. A complete profit maximization is, therefore, hardly expected. An efficient cost-minimizing production, on the other hand, is a plausible behavioral assumption.

Moreover, in practice, the levels of some characteristics may be easier to control, than the levels of others. For example, farmers may easily affect the degree of cleanness of the cotton fibers, but controlling their strength requires much more expertise. Thus, from a variety of practical reasons, such as insufficient know-how, farmers may optimize with respect to only a subset of characteristics. In the general case, the netputs vector is partitioned into two subsets $y = (y_o, y_n)$, where y_o includes netputs, which are chosen optimally while y_n include the others. In this case, Eq. (4) is modified to

$$\pi(\tilde{y}_o, \tilde{y}_n) \geq \pi(y_o, \tilde{y}_n) \quad \forall (y_o, \tilde{y}_n) \in Y. \quad (5)$$

The essence of our nonparametric test, presented below, is to identify these two subsets.

Structures of Typical Panel Data and Technology

The data available for the researcher are $N \cdot T$ (NT) observations $y^{1,1}, \dots, y^{N,T}$ regarding the actual netput choices made by N competitive growers, each over T years. Each of these observations corresponds to a set of market conditions given by the input price vector, $w^{i,t}$ and the output price as a function of the various characteristics, $p^{i,t}(\cdot)$.

In addition, each observation is characterized by possibly different technological and environmental factors, denoted by a vector $\tau^{i,t} \in \mathcal{R}^m$, determining the set of feasible netput vectors — the technology. This description presumes that the technological-environmental conditions may vary over time and across producers. Each of the growers, of course, knows the technological-environmental parameters which he faces. These parameters, however, are not included in a typical data set and thus are not known to the researcher.

Since, the technology and environmental conditions may vary from one observation to another, each observation is characterized by its own production set — $Y(\tau^{i,t})$. Thus we are dealing with a *NT* family of production sets $\mathcal{Y} = \{Y^1, \dots, Y^{NT}\}$.

Technological Restrictions

In the general case, where no additional assumptions are made concerning the family $\mathcal{Y}$, the pooled data are of no use for testing behavioral rules or technological restrictions. For example, consider the technology $\mathcal{Y} = \{\{y^1\}, \dots, \{y^{NT}\}\}$. If this is the family of technologies, then any choice set of a farmer at a specific year is limited to the corresponding actual choice. In such a case, the observed netputs are also the maximizing netputs and the data is, trivially, found consistent with profit maximization.

To avoid such a degenerate analysis, we follow Bar-Shira and Finkelshtain (1997) to adopt a particular structure for the family $\mathcal{Y}$, which is rich enough to model real world technological variations across firms and over time, yet is sufficiently restricted to allow a meaningful nonparametric analysis.

The proposed structure amounts to the assumption that the technologies, associated with the various observations are rankable. Formally,

Definition 1: Rankable Technological Variations (RTV) *A family of technologies $\mathcal{Y} = \{\{Y^1\}, \dots, \{Y^{NT}\}\}$ exhibits RTV, if and only if its members can be sorted into a*

nested family such that $Y^1 \subseteq Y^2 \dots \subseteq Y^{NT}$.

RTV means that the technology employing by a certain firm at a certain year may differ from the technology that another firm faced in another year. However, one of the two dominates the other. This structure accounts for Hicks neutral technological variations, but also permit many other type of technological changes. The only restriction is, that one production set is either contains or contained in any other production set.

As aforesaid, in the sequel we will be interested to examine optimization with respect to some subsets of netputs. In such cases, the technology will be represented by the “netput requirement set” (NRS), defined by $V(y_n) = \{y_o | (y_o, y_n) \in Y\}$. The RTV assumption, will then be replaced by an analogous assumption concerning the set $V(y_n)$. In particular, we shell assume that $\forall Y^j \in \mathcal{Y}$ and $y, y' \in Y^j$, either $V(y'_n) \subseteq V(y_n)$ or $V(y_n) \subseteq V(y'_n)$. This assumption means that the marginal rate of substitution between any two elements of y_o is invariant with respect to technological variations and the level of y_n . The latter is exactly the definition of separability of y_o from y_n and the technological variation in the production technology. Graphically, it means that the technological variations renumber the isoquant level but do not change their shape; that is the isoquant map is unchanged by the technological variations.

3. Testing Farmers Response to Hedonic Pricing

Nonparametric tests for profit maximization, cost minimization and a variety of restrictions on the underlying technology are well known in the literature (*e.g.*, Hanoch and Rothschild, Varian, Chavas and Cox, Fawson and Shumway, Silva and Stefanou, Chalfant and Zhang, and Bar-Shira and Finkelshtain). These tests, however, do not explicitly account for the above pricing system and optimization with respect to a subset of netputs. In this section we extend the above frameworks to fill this gap.

The Theoretical Basis

Given information about the component and input prices, and netput choices, the nonparametric procedure facilitates to test whether the observed data are consistent with profit maximization or some other partial optimization procedure. Specifically, one can test whether the producer fully (or partially) accounts for the component pricing.

To facilitate the test we need to introduce a few concepts of revealed technological superiority. These concepts are based on the ideas presented by Varian (1983) in the context of a revealed preferences approach to consumer theory, and by Bar-Shira and Finkelshtain in the context of pooled production data. The analogy to analysis of consumers' behavior is insightful. In analyses of consumer behavior, one does not observe the consumer's objective function – his utility. However the budget constraint is observable, which suffices to test whether a given data set is consistent with constrained utility maximization. For this purpose, Varian (1982) proposed the generalized axiom of revealed preferences (GARP).

In analyses of producer behavior, the value of the producer's objective function – his profit or cost – is observable, but the technological constraint – the production set or netput requirement set – is not. Moreover, technological variations over time and across growers mean that the production set varies between observations. Below we show that in such

cases a procedure that resembles GARP can be employed to non-parametrically test for consistency of production data with profit maximization or partial optimization problems.

Formally, let $i, j \in \{1, \dots, NT\}$. When we observe $\pi(p^i, w^i, y_o^i, y_n^i) < \pi(p^i, w^i, y_o^j, y_n^i)$ we say that the technology $Y^{t'}$ was directly revealed as superior to that of Y^t ($Y^{t'} R^d Y^t$), for, under profit maximization, had $y^{t'}$ been feasible at year t , it would have been chosen. When technological superiority is revealed through a third party, $Y^{t''}$, we omit the word “directly” and denote this case by: $Y^{t'} R Y^t$. In both cases the binary relation $Y^{t'} \subseteq Y^t$ holds.

In the context of production analyses, a more meaningful name for GARP would be the “Generalized Axiom of Revealed Technological Superiority” (GARTS). The formal definition is given by:

Definition 2: GARTS – $Y^{t'} R Y^t$ implies $p^{t'} y^{t'} \geq p^{t'} y^t$.

Before turning to the test procedure itself, it remains necessary to clarify the term “Rationalizing,” which simply means that there exists a family of ordered technologies under which profit maximization would have generated the observed data. Formally,

Before turning to the procedure itself, we must, formally, define the optimization behavior and what is meant by consistency of the data with this behavior.

Definition 3: Rationalizing Pooled Data with Partial Optimization A family of production sets $\{Y^1\}, \dots, \{Y^{NT}\}$ rationalizes observed producer behavior if $\pi(p^i, w^i, y_o^i, y_n^i) \geq \pi(p^i, w^i, y_o, y_n^i) \quad \forall y_o \in V^i(y_n^i)$.

Theorem 1 presents the theoretical basis for the test procedure. Condition 2 of the Theorem facilitates a simple test for partial optimization jointly with technological variations of the form defined by Definition 2 and its extension.

Theorem 1: Consider a set of observations $y^{11}, \dots, y^{NT}$, corresponding to market condi-

tions given by $(p^{1,1}, w^{1,1}) \dots, (p^{N,T}, w^{N,T})$. The following statements are equivalent: (1) There exists a nested family of production sets that rationalizes the data with partial optimization. (2) The sub data, p, w_1, y_1 satisfy GARTS. (3) There exists a nested family of closed, convex, negative monotonic production sets that phnc-rationalizes the data.

Proof: (1) $\Rightarrow$ (2)

We must show that $p^i y^i < p^i y^j$ implies $Y^i \subset Y^j$. Suppose that this was not the case, so $p^i y^i < p^i y^j$ and $Y^i \not\subset Y^j$. But nestedness implies that if $Y^i \not\subset Y^j$, then $Y^j \subset Y^i$. The latter, however, means that y^j was feasible to the producer, when the choice y^i was made, contradicting profit maximization.

(2) $\Rightarrow$ (3)

We now have to show that there is a nested family of "nice" production sets the phnc-rationalize the data. The proof is constructive. The first step in the construction is sorting of the data into $L < NT$ sets, $\phi^1, \dots, \phi^L$, such that

$$\forall y^i, y^j \in \phi^l, p^i y^i \geq p^i y^j \text{ and } p^j y^j \geq p^j y^i, l \in 1, \dots, L.$$

Moreover, $\phi^l \subseteq \phi^{l+1}$ and

$$y^h \in \{\phi^{l+1} \setminus \phi^l\} \leftrightarrow \text{exit } y^i \in \phi^l, \text{ such that } p^i y^h > p^i y^i.$$

Since the data passes GARP this construction is well defined. In particular, note, that each netput vector is contained in at a least one ϕ , for as, even if the technology of a certain observation, i , is revealed superior to all other observations, it is contained in the singleton $\phi^L = \{y^i\}$.

Now let

$$\phi^{-i} \equiv \bigcap_{\phi^l \ni y^i} \phi^l.$$

ϕ^{-i} is the smallest ϕ that contains y^i . We now construct the i th observation production set as

$$Y^i \equiv \text{com}^- \{\phi^{-i}\} \quad i \in \{1, \dots, NT\}.$$

As needed, the above construction implies that $\forall i \in 1, \dots, NT \quad y^i \in Y^i$, namely, y^i is feasible under Y^i . Also the family $\{Y^1, \dots, Y^{NT}\}$ exhibits the required nestedness property and each of the production sets is closed, convex and negatively monotonic. It is now left to show that the above family phnc-rationalizes the data.

Thus suppose that $y \in Y^i$, we must show that $p^i y^i > p^i y$. By construction, $\forall t^j > 0$, a vector $e^j < 0$ and $y^j \in \{Y^i\}$, it follows that $t^j p^i (y^j + e^j) \leq t^j p^i y^i$. Summing over j we find

$$p^i \sum_{j=1}^i t^j (y^j + e^j) = p^i y \leq p^i y^i,$$

where the equality follows from the fact that $y \in Y^i$. □

Theorem 1 establishes that pooled data can be utilized to test for profit maximization. The procedure is based on condition 2 of the Theorem and is implemented via simple sorting algorithm. It facilitates the test of both usual profit maximization and profit maximization with full awareness for the component pricing. The only difference in the test procedure is the value substituted for p .

4. The Israeli Cotton Industry

As we think that some of the institutional and historical facts are important for the understanding of the problem, we briefly review the development of the industry and its main institutions.

Historical Perspective and the Industry Markets

The Israeli cotton industry was established four decades ago, based on Californian imported technology. The cotton industry grew very rapidly until recent years and has become the most important field crop in the Israeli agriculture. Recently, several consecutive droughts had lead to a drastic reduction in water quotas allocated to agriculture and caused a sharp reduction in the cotton acreage, which currently stands on about 30,000 Acres. However, recent increase in world prices, accompanied with an increased use of recycled water in cotton irrigation and new water saving technologies seems to change the situation over.

The two main varieties are the medium-length-fiber Acala and the long-size-fiber Pima, where the former constitutes 70% of the quantity produced. 10-15% of the industry product is consumed by the domestic textile industry, while the rest 85-90% is exported. Most of the industry export was channeled to Western Europe, of which it supplies 6% of its consumption. In total Israel produces 0.57% of the world total production, consumes 0.1% of the world consumption and export close to 2% of the world market size of 20.7 million cotton packages.

Institutional Description

The Israeli Cotton Marketing Board monopolizes the marketing of the product of all the Israeli growers. The board serves 350-500 growers, among which 50% are kibutsim (collective villages) that produce more then 90% of the total industry product. The cotton

marketing board has been established in 1956 as a non-to-profit organization, owned by the growers, government and the textile industry. The board activities are financed by the growers, either via direct collection of taxes or via discount of commission from the sales revenues. The board activities include marketing, pest management and R&D.

Pooling and Component Prices System

The marketing board does not commit itself to a certain price, but rather transfer the net returns from the actual market sales. The transfer is done by means of sophisticated pooling system, supported by a complex credit system. For each growing season and each brand (Acala and Pima) a separate pool system is established, through which the net return is distributed between the growers of the particular season and brand.

The essence of the 'pool' system is as follows: A Base Priced is determined according to the international price of the given standard and brand (SLM 1.1/16"). A quality differential pricing system is then added to the Base price. The system includes premia and fines according to five characteristics: fiber length, fiber strength, fiber grade (color and percentage of trash), fiber fineness and fiber stickiness.

Description of the Data Base

The data set was gathered by the Israeli Ministry of Agriculture extension. The farms from which the data was collected belong to three geographical and climatic regions: the Carmel beach region, Menashe region and the Hefer valley. All these region belong to the northern central part of Israel.

The data base contains a detailed panel data regarding cotton production for the years 1984-1989 and 41 growers. After the sorting the data and the removal of unreasonable data we have left with 29 growers. Many of the growers cultivate several land-plots and so, we end up with 2500 observations regarding 52 variables that describe in details the production

process, the price system and environmental variables such as temperatures, participation, length of day etc'.

5. The Results

As aforesaid, we first tested for GARP using all the 208 observations. The maximum possible number of violations of GARP is 21,528. We found less than 300 violations, namely less than 1.5% rate of violations. Hence we conclude that the data satisfies GARP and producer do minimize cost.

In the second stage we tested for the two existence of WACM with the two alternative cost minimization hypotheses. To be able to test for WACM we must employ the observed levels of gross output and hedonic revenue. To account for the technological variations between producers, we tested for WACM for each producer separately. To account for variations in technology over time, we allowed 10% data errors. The results are reported in the table below.

Table 1: WACM Violations

	<u>Number of Observation</u>	<u>Violations given y</u>	<u>Violations given R</u>
Farm I	44	10	10
Farm II	23	4	1
Farm III	11	0	0
Farm IV	87	37	32
Farm V	23	0	0
Farm VI	20	2	0
Total	208	53	43

Thus there are less violations of WACM, when the hedonic revenue, rather than gross

output is taken as the constrained in the cost minimization problem. However, employing a usual statistical test for difference between proportions, we find that the above difference is not statistically significant. Even if some violations are due to statistical errors, but one behavioral hypothesis is correct, one would expect to find significant difference between the number of violation under the two.

Since the data pass the first stage test and satisfy GARP we conclude that the growers minimize cost. However, in the second stage test we do find significant number of violations. Moreover, no significant difference between the two cost minimization hypotheses was found. We therefor conclude that farmers do not fully account for the component pricing. This should be a warning flag for policy makers. Sorting, grading schemes and components pricing system cost money. If farmers do not appropriately response to these system, then efficiency consideration require their elimination.

Certainly this paper represents only the first step toward a comprehensive study of the subject. However we think that the ratio of demand vs. supply studies of component pricing is to low. We now know how to estimate hedonic price econometrically or based on market surveys. The open question is, whether these are useful as an incentive scheme for producers.

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CHAPTER 11: MEASURING THE MONOPOLISTIC POWER OF A MARKETING AGENCY—APPLICATION TO ISRAELI CITRUS EXPORT

Original Version: Yael Kachel and Israel Finkelshtain

1. Introduction

Potentially, pooling may give the marketing agency the volume or product breadth needed to exercise power in its customer or input markets. However, in real world, for a variety of reasons the export firm may not exploit its potential market power. Important reasons for not exploiting the potential of market power are: 1) contracts or international agreements that forbid exercising of market power; 2) deterrence of potential competitors from entering the market; 3) political considerations and marketing inefficiencies that lead to imperfect optimization. The third argument is especially important in the case of agricultural export by government agencies. The purpose of this chapter is to develop a methodology for the measurement of the potential market power and its actual exploitation by a multiproduct, multimarket marketing agency.

The measurement of noncompetitive conduct, based on market data, is the subject of a recent extensive literature that belongs to the growing field of "New Empirical Industrial Organization" (NEIO) (see Bresnahan 1989 and references therein). A few of these studies have focused on export markets for agricultural goods. These include Buschena and Perloff's (1991) analysis of coconut oil export, Karp and Perloff's (1989, 1993) studies of the rice and coffee markets, Lopez and You's (1993) study of the Haitian coffee export and the recent study of Deodhar and Sheldon (1995) of the German import market for bananas. Love and Murniningtyas (1992) estimate simultaneously market power exertion in both wheat imports and wheat sold in the local market by a government trade agency. The typical firm portrayed in these studies exports (or imports) a single product to a single market. Noncompetitive conduct in such a framework is confined to monopoly markup pricing, that is, charging a price above marginal cost.

In real world, however, many export firms are engaged in multiproduct exports and sales to many markets. In such a setup, noncompetitive conduct is much richer and

includes, in addition to markup pricing, third degree price discrimination between markets and cross subsidization across products. The paper's methodological contribution is the extension of existing methodologies of market power estimation to account for multiproduct firms and third degree price discrimination. It is shown that estimation of market power in this generalized framework does not entail any additional econometric or computational difficulties. On the contrary, while the single market, single product framework requires data concerning variables that affect the firm's cost, only marketed quantities and prices are required in the current approach. Moreover, the necessary condition for identification of market power in the single market case—rotation of either the demand or cost function (see Bresnahan 1982)—is not necessary in the generalized setting.

Empirically, the paper's objective is to provide additional evidence regarding the competitive nature of international trade in fresh agricultural products. Recently, a variety of international agreements were signed in order to reduce trade barriers, such as high tariffs, import quotas and excessive subsidization of domestic producers. An additional clear obstacle for free trade is noncompetitive conduct on the side of exporting firms. Exploitation of market power by exporting firms hurts consumers in the importing country and leads to a reduced trade volume and welfare loss. However, unlike other trade barriers, it enhances the profits of both domestic and foreign producers of the product or its substitutes. This may provide the explanation why international agreements and discussions overlook this issue. Most countries protect consumers from noncompetitive conduct of domestic firms by means of an extensive anti-trust legislation. They ignore, however, the possibility of such behavior by foreign exporters.

The markets of most internationally traded goods are characterized by a large variety of close substitutes with small market share for each. On the contrary, many fresh agricultural products are produced in certain seasons only by a few countries, which gain, each, a considerable market share. Moreover, in many exporting countries agricultural export is organized by so-called "one hand" exporting firms. That is, competition among exporters from the same country is avoided by institutional arrangements. Therefore, markets for agricultural import goods may be exposed to noncompetitive conduct. If market power is actually exercised, then there is a need for international anti-trust agreements, which may

elevate trade volume and enhance welfare.

The only study (which we are aware of) that applies the NEIO methods to examine this question in the context of international trade in fresh agricultural products is Deodhar and Sheldon (1995). The results of these authors support the hypothesis of noncompetitive conduct in the German market for imported bananas. The current paper analyzes a data set that describes Israeli citrus exports to England and Germany, during the years 1983-1994. These data facilitate to examine whether the CMBI (Citrus Marketing Board of Israel) exercised monopoly market power and, in particular to test for the following hypotheses : 1) third degree price discrimination between the German and English market; 2) cross subsidization among exported citrus varieties; 3) competitive conduct. Contrary to Deodhar and Sheldon's 1995 results concerning the banana market, our results support the hypothesis of competitive trade. While the CMBI enjoyed considerable market shares, owned a differentiated brand name and monopolized the entire Israeli citrus export, we find no evidence for noncompetitive conduct.

2. Institutional Description

Until 1991 Israeli citrus fruit was exported by a compulsory marketing board - the CMBI (Citrus Marketing Board of Israel). Dissatisfaction with the performance of the board led to the liberalization of exports. The board still exists but is no longer actively involved in selling the citrus crop. An important justification for the establishment and maintenance of a centralized export system is the possibility to use market power in export markets and price discrimination between different markets. A frequently used argument to support the CMBI was that the CMBI as the sole exporter of Israeli citrus fruit had the possibility to exercise market power and in this way to increase export revenues for Israeli citrus growers.

Indeed, the CMBI was aware of the possibilities to exploit market power and supported a study that designed an applicable model of optimal marketing policy (Kohn and Plessner 1973). Based on the demand estimates for 8 Israeli citrus varieties in 5 European markets, these authors proposed an optimal pricing policy, that exploits the CMBI's market power and variations in elasticities across markets and products. Today, after liberalization of

citrus export, it is argued by executives of export firms and marketing experts (e.g. P.O.C 1994) that "wild" competition among Israeli citrus exporters depresses prices and revenues.

The main markets for Israeli citrus exports are Western European countries. In these countries citrus fruit is a regular item at winter time in the diet of most consumers. Total fresh citrus consumption is more or less stable. The overall demand for citrus is inelastic but we can expect that the import demand function for Israeli citrus fruit in different export markets will be quite elastic because there are close substitutes - citrus fruit from other exporting countries.

Oranges and grapefruit of different varieties constitute as much as 90% of Israeli citrus exports (CLAM). Several stylized facts support the hypothesis that the CMBI had the potential to exercise power in the markets for these varieties. During the 60's and 70's, Israel was one of the main suppliers of oranges and the main supplier of grapefruit to European markets. Market shares in Western Europe in the mid-70's were close to 30% for oranges and about 65% for grapefruits. Market shares of Israeli citrus have been falling substantially in the last decade. Today the average market share of Israeli oranges in the main European markets is lower than 5%, while on European grapefruit markets Israel is still an important competitor with a market share of about 20%.

Nevertheless, in the main supply season and the main markets the market share of Israeli oranges can be quite substantial even today. Market shares in the English and German markets for oranges and grapefruit are reported in Figures 1-4. The figures show that, even today, Israel's market share in the English market for oranges and grapefruit in the winter season is about 30%. In the German market for grapefruits the share in some months is as high as 60%.

Large market shares suggest, of course, that there may be a potential for market power exploitation. An additional indicator for such a potential are large advertisement expenditures. It is well known (e.g. Tirole 1988) that competitive firms do not have an incentive to advertise. Moreover, *ceteris paribus*, the less elastic is the demand function, the larger is the share of revenues that should be spent on advertisement. The CMBI invested a lot of money in advertising and promotion and successfully established a differentiated brand name for Israeli citrus - JAFFA.

Evidence in support of this success are provided by Kirsch's (1993) study of German consumers preferences for oranges from different origins and the P.O.C (1994) consumer research in the English and Swedish market. Moreover, a recent published article in the Fresh Produce Journal (October 1995) reports the following findings of an A.G.B (a British market research firm) study of the English market: 1) the unprompted awareness rate of the "Jaffa" brand equals 72% ; 2) *ceteris paribus*, 62% of the consumers prefer the "Jaffa" oranges; and 3) 42% are willing to pay a small price premium for this brand.

Still, citrus is a low involvement good and it is not clear whether a high brand awareness really leads to inelastic demand. This is especially true in the face of declining availability of Israeli citrus in the last years which may force consumers to look in several shops if they really want to buy Jaffa-citrus.

3. A Model of Exporter's Behavior

This section presents the methodology. Our general approach belongs to the school of NEIO, that is, firms actual behavior is inferred from market data, only. Time series of prices and quantities are analyzed in order to evaluate both the potential for market power and its actual exercising (Bresnahan 1989, Carlton and Perloff 1990, pp.387-388). The first step in this approach is the estimation of market demand functions, followed by the estimation of an equation that represents the firm's behavior.

3.1. Demand and Cost Structure

The multiproduct marketing firm exports V products to M distinct markets. The residual demand function for a product v at time t and market m is given by the following general form:

$$p_v^{mt} = f_v^m(q_1^{mt}, \dots, q_V^{mt}, X_v^{mt}), \quad (1)$$

where p_v^{mt} is the import price for product v in market m at time t (in destination market currency), f_v^m is the inverse residual demand function for product v in market m , $q_1^{mt}, \dots, q_V^{mt}$ are import quantities of the various products and X_v^{mt} a vector of exogenous variables. These include: import quantities by competitors, expenditure for citrus, trend, season and month effects.

The formula in (1) implies that the various exported products are either demand substitutes or complements. These interdependencies in the demand are important factors in determining the firm's marketing behavior.

The exporter's cost function is given by

$$C^t(Q_v^t, \dots, Q_V^t, Z^t) \quad (2)$$

where

$$Q_v^t = \sum_{m=1}^M q_v^{mt}$$

is the total export of product v at time t , C^t is the total exporting cost at time t and Z^t is a vector of exogenous variables affecting export cost. By equation (2), exporting cost depends on the vector of total export of each good. This formulation reflects the possibility that there are different cost to export different products. Moreover, the formulation is general enough to allow both scale and scope economies in the export activities.

3.2. Profit Maximization

Given the demand and cost structure, described by (1) and (2) the export firm maximizes its profit by choosing the quantity of each product to be exported to each target market, namely

$$\max_{q_1^{1t}, \dots, q_V^{Mt} \geq 0} \sum_v^V \sum_m^M s^{mt} p_v^{mt} q_v^{mt} - C^t(Q_v^t, \dots, Q_V^t, Z^t), \quad (3)$$

where s^{mt} is the exchange rate (exporter's currency per unit of the destination market currency). Equation (3) emphasizes that the exporter accounts for interdependencies among the various exported commodities, in both the demand and cost functions.

The necessary condition for maximum of (3), with respect to the quantity of a product i exported to market j , at time t is given by

$$s^{jt}(p_i^{jt} + \sum_{v=1}^V \frac{\partial p_v^{jt}}{\partial q_i^{jt}} q_v^{jt}) = \frac{\partial C^t}{\partial Q_i^t}. \quad (4)$$

On the left hand side of (4) is the marginal revenue, translated into the exporting firm's currency, and on the right hand side is the marginal cost (with respect to variety i).

For interpretation, it is convenient to write expression (4) in terms of the price flexibilities,

$$\frac{s^{jt} p_i^{jt} - C_{Q_i}^t}{s^{jt} p_i^{jt}} = - \sum_{v=1}^V \frac{R^v}{R^i} \mu_i^v, \quad (5)$$

where $C_Q = \frac{\partial C}{\partial Q}$, $R^v = p_v^{jt} q_v^{jt}$ and μ_i^v is the flexibility of price for product v with respect to the quantity of product i . It follows that a product which is a demand complement (substitute) of product i contributes to smaller (larger) mark-up in the price of good i .

If the export firm perfectly optimizes, then the $V \cdot M$ equations, of the form of (4), characterize its behavior. However, in real world, for a variety of reasons the export firm may not exploit 100% of its potential market power. Important reasons for not exploiting the potential of market power are: 1) contracts or international agreements that forbid exercising of market power; 2) deterrence of potential competitors from entering the market; 3) political considerations and marketing inefficiencies that lead to imperfect optimization. The third argument is especially important in the case of agricultural export by government agencies.

Accordingly, we add parameters λ_{iv}^m $v \in 1, \dots, V$, $m \in 1, \dots, M$, in equation (4) to assess the degree of exploitation of various possibilities for noncompetitive conduct. Note, that *a priori*, there is no reason for equality of the various λ 's. For example, if agreements that forbid exercising of market power are signed with only a subset of importing countries, then one would expect variation in λ 's across countries. Similarly, skills and efforts of government employed salesmen for various products and in different markets are usually heterogeneous, leading to variations of the λ 's across markets and products.

Equation (4) is rewritten as

$$s^{jt}(p_i^{jt} + \sum_{v=1}^V \lambda_{iv}^m \frac{\partial p_v^{jt}}{\partial q_i^{jt}} q_v^{jt}) = \frac{\partial C^t}{\partial Q_i^t}. \quad (6)$$

Only if $\lambda_{iv}^m = 0 \forall v \in 1, \dots, V$ $m \in 1, \dots, M$, will the price of the i th product reduce to its competitive level, $C_{Q_i}^t$ – the marginal cost of exporting product i . Any $\lambda_{iv}^m \in (0, 1]$ indicates a noncompetitive conduct.

4. Structural Estimation of Market Power Exploitation

Following the NEIO literature (Bresnahan 1989; Carlton and Perloff 1990), this section shows that it is possible to use estimation techniques based on quantity and price data for evaluating the actual exercising of market power. The observed price and quantity data provide us with information on price formation and make it possible to learn about the behavior of firms in this market. In a market with perfect competition prices will be equal to marginal costs. If a firm believes that it can affect price by altering its output, then it does not set price equal to marginal cost. The firm will increase its output until its incremental profit is zero (marginal revenue = marginal cost).

As mentioned in the introduction, the existing empirical studies on estimation of market power in international markets are based on single market price and quantity data (see Buschena and Perloff 1991, Karp and Perloff 1989, 1993, Lopez and You 1993, Deodhar and Sheldon 1995). The behavioral equation (6) provides the basis for the estimation. Marginal cost are not observed, directly, and therefore are expressed as function of observed variables influencing marginal costs. Prices are specified as a function of these variables and the second term in equation (6). The derivatives of the form $\frac{\partial p_i^{mt}}{\partial q_i^{mt}}$ are taken from the estimates of the demand equation (1).

It was shown by Bresnahan (1982) and Lau (1982) that with a single market data set, the parameter λ is identifiable only if the demand (or cost) function rotates. If the demand function is additively separable in own price and the exogenous variables, then changes in these variables shift the demand curve inward or outward parallel to the original curve. This fact does not allow an identification of the competitive structure of the market because a parallel move in demand changes a competitive and a monopolistic equilibrium in a similar manner and the two are not distinguished. The problem can be eliminated by specifying a non-separable demand function with a variable that shifts the slope of the demand curve. This has been forcing researchers to include (in some cases *ad-hoc*) variables that rotate the demand curve.

If a firm supplies two (or more) markets, the estimation of the λ 's does not require data about variables that affect cost and the demand function can be specified in the usual additive form. These are important advantages since contrary to demand data, it is often

not an easy task to specify the marginal cost function in terms of available data. Also, it is not necessary to search for exogenous variables that change the slope of the demand function.

To see this, consider the cost structure from (2), which presumes that marginal cost in exporting a certain product to the various markets is identical. Under this assumption, the actual use of potential market power is identified by equating the left hand side of (6) for a certain good and different markets. That is, suppose that a product i is exported to both market m and m' , then

$$s^{mt}(p_i^{mt} + \sum_{v=1}^V \lambda_{iv}^m \frac{\partial p_v^{mt}}{\partial q_i^{mt}} q_v^{mt}) = s^{m't}(p_i^{m't} + \sum_{v=1}^V \lambda_{iv}^{m'} \frac{\partial p_v^{m't}}{\partial q_i^{m't}} q_v^{m't}). \quad (7)$$

The estimation procedure proceeds as follows. The first step is the estimation of the inverse residual import demand functions for different markets and different products. These provide the information regarding the possibility to exercise market power in the various export markets. If demands are not perfectly elastic there is scope for the exporting firm to use market power and the analysis should proceed to the next step. In the second step equation (7) is estimated by the following simple linear regression

$$s^{mt}p_i^{mt} - s^{m't}p_i^{m't} = \sum_{v=1}^V [\beta_{iv}^{m'} s^{m't}q_v^{m't} - \beta_{iv}^m s^{mt}q_v^{mt}], \quad (8)$$

where the β 's are the regression coefficients. Note that only price and quantity data are required for the above estimation.

In the third step λ_{iv}^m is evaluated by

$$\lambda_{iv}^m = \frac{\hat{\beta}_{iv}^m}{\hat{\sigma}_{iv}^m}, \quad (9)$$

where $\hat{\beta}_{iv}^m$ and $\hat{\sigma}_{iv}^m$ denote estimates of the β s and the derivatives of the inverse residual demand functions, respectively.

5. Demand Estimation

In this section the above methodology is applied for the analysis of the Israeli Citrus export to Western Europe. We commence with the estimation of the demand equations for both oranges and grapefruit, in both Germany and England. Orange- and grapefruit exports together represent about 90% of total fresh citrus exports from Israel (CLAM). We then proceed to estimate the behavioral relationships.

5.1. Estimating import demand functions for Israeli oranges

The most important markets for Israeli orange exports are England, Scandinavia and Germany. Here, we analyze the English and German markets which import about 45% of the Israeli orange exports (CLAM). The following inverse import demand function for Israeli citrus fruit (residual demand curve) is estimated for each market:

$$p^t = f(q^t, X_i^t) + \epsilon_o^t, \quad m = E, G \quad (10)$$

with G and E denoting the German and English markets, respectively, t is the date, p^t is the import price for Israeli oranges, q^t , import quantities of Israeli oranges, X_i^t , a vector of additional explanatory variables. A random disturbance is added in terms of a random variable ϵ^t with the usual assumptions: $E(\epsilon^t) = 0$, $V(\epsilon^t) = \sigma \forall t$ and $Cov(\epsilon^t, \epsilon^{t'}) = 0 \forall t, t'$. Explanatory variables included in the demand equation are import quantities of all other oranges, quantities of possible substitutes (easy peelers, grapefruits), expenditure for citrus and a trend variable. To allow for cross subsidiation across products quantities of Israeli grapefruit imports are included. The demand equations are specified in the inverse form because in the citrus trade usually quantities exported are determined first (in the short run).

Monthly data from 1983 till 1994 are used for estimating the import demand functions (Germany 01/83 till 06/94, U.K. 01/86 till 06/94). The import quantities are taken from import statistics of each country. The unit value based on the same statistics is used as an approximation of import prices for Israeli oranges.

In order to verify if unit values are good indicators for orange prices, unit values and wholesale prices are compared. German wholesale prices used are average prices from 7 different wholesale markets, whereas the wholesale prices from England are just from one

market (New Covent Garden, London). Therefore it seems reasonable that correlation between unit values and wholesale prices are smaller for England ($r = 0.66$) than for Germany ($r = 0.86$). Price comparison shows that there is a stable relationship between German unit values and German wholesale prices for the entire observation period.

English unit values and wholesale prices show similar behavior in the period till 1993. In this period the correlation coefficient is 0.71. From 1993 wholesale prices in England went up while unit values fell. A possible reason for this fact is a change in data gathering methods with the abolition of border controls inside the European community. According to trade sources it seems more reasonable that prices for Israeli oranges in England rose in 1993 and 1994. But because we do not know for sure which data are correct the import demand function for England is estimated with both unit values and with wholesale prices. Expenditure for citrus is measured by the total monthly import value for all citrus fruit. A trend variable is included in the equation to account for changes in consumer preferences. All data are deflated by the consumer price index of the destination market (basis 1985). Months with imports from Israel less than 100 tons are not included in the estimation.

The estimation results are shown in Table 1.

Table 1: Demand for Israeli Oranges

		Germany (n=81)		England (n=69)	
<u>Dependent Variable:</u>		<u>Orange Price</u>	<u>S.E.</u>	<u>Orange Price</u>	<u>S.E.</u>
Independent Variables:					
Quantity	Israel	-17.48	(8.22)	$-0.18 \cdot 10^{-4}$	$(0.33 \cdot 10^{-5})$
Quantity	others	-184.66	(37.54)	$-0.11 \cdot 10^{-4}$	$(0.29 \cdot 10^{-5})$
Quantity	easy-peelers	-51.18	(10.21)	$-0.17 \cdot 10^{-4}$	$(0.30 \cdot 10^{-5})$
Quantity	grapefruit	-36.65	(39.61)	$-0.25 \cdot 10^{-4}$	$(0.75 \cdot 10^{-5})$
Quantity	Israel grapefruit	-4.79	(8.03)	$-0.39 \cdot 10^{-5}$	$(0.18 \cdot 10^{-4})$
Expenditures		265.51	(43.47)	$0.62 \cdot 10^{-7}$	$(0.11 \cdot 10^{-7})$
Trend		-42.46	(13.72)	-0.0033	$(0.67 \cdot 10^{-3})$
Season	1984/85	228.61	(46.78)	N.A.	(N.A.)
Season	1989/90	73.18	(42.81)	-0.056	(-0.058)
Constant		892.31	(278.62)	5.66	(0.09)
R^2		0.88		0.78	
DW		1.94		1.92	

Functional forms are chosen on the basis of explanatory power. For both countries a semi-logarithmic demand function seems to fit the data best. However, for Germany the independent variables are specified in logarithms, while for the English market the dependent variable is in logarithmic terms. The estimated coefficients are significant at the 5% level based on a two-sided t-test with the exception of the coefficient for quantities of Israeli grapefruits, the coefficient for total grapefruit imports in the German market and the dummy for season 1989/90 in the English market. In the German market the dummy for season 1989/90 is significant at the 10% level. Both imports of oranges from Israel and the other competing countries have a significant negative effect on prices of Israeli oranges. Nevertheless, own price flexibilities for import demand of Israeli oranges are quite small. For German import demand the price flexibility calculated at the sample average is -0.022 and for English import demand -0.14.

The estimation results show that Israeli oranges supplies can influence prices but the effect is small, especially in Germany. An increase in the average monthly import quantity of England by one percent (80 tons) will cause the average price of 210.7 Pound Sterling

per ton to fall by 0.29 Pound. The same change in Germany (62 tons) decreases the average import price of 788.9 DM per ton by 0.17 DM. Import demand in England is less elastic than in Germany because the market share of Israeli citrus is comparably larger, especially in the last years. Additionally, in England there seems to be a market segment which values the special qualities of Israeli Shamouti oranges in comparison to other oranges and this is decreasing their substitutability (see Fresh Produce Journal 1995).

An increase in total expenditure for citrus has a significant positive effect on the import demand for Israeli oranges. The coefficient of the trend variable is significantly negative in both markets, suggesting an adverse change in consumers tastes. The coefficients for the quantities of the substitute easy peelers are significant in both markets and show the expected sign. The coefficient for grapefruit quantities shows the expected sign in both markets but is significant just in the English market, suggesting that there are differences between English and German orange consumers in their perception of grapefruits as a substitute for oranges. Two dummies in the German import demand function account for two exceptional seasons. In the 1984/85 season bad weather led to a large decrease in orange exports from Spain - the main supplier of European orange markets. The season 1989/90 was also characterized by adverse weather conditions in Spain which caused many quality problems with Spanish fruit.

Several different estimation methods were employed and compared and the main estimation results were found pretty robust. In order to correct for autocorrelation of residuals, while estimating the import demand functions, we employed the exact ML method for AR(1) correction (Pesaran and Pesaran 1991). Finally, an attempt to estimate the import demand function for Israeli oranges in England with wholesale prices instead of unit values yielded results similar to the original estimation but with a lower explanatory power ($R^2 = 0.52$). The significance level of the coefficient for the quantities of Israeli oranges imported is close to 10% and prices are less flexible than in the original estimation results (price flexibility equals -0.067).

To summarize, the estimation results for the import demand equations show that there is some potential for the Israeli citrus industry to employ market power in orange export markets. In particular, there is potential to increase prices by price discrimination

between the German and English markets. However, this potential is small.

5.2. Estimating import demand functions for Israeli grapefruits

Grapefruits are - after oranges - the second most important export product of the Israeli citrus industry. Roughly, 35% of total Israeli grapefruit exports are exported to Germany and England. The customs data which are used to estimate import demand functions for Israeli grapefruits do not differentiate between red grapefruit and white grapefruit. In recent years red grapefruit exports have been expanding, while white grapefruit exports have been falling. There is substantial evidence that red and white grapefruit are perceived as differentiated products with different demand curves. To correct for the potential bias we include as an explanatory variable the seasonal share of white grapefruit in Israeli grapefruit exports to each market. Table 2 reports the estimation results.

Table 2: Demand for Israeli Grapefruits

		Germany	(n=123)	England	(n=61)
Dependent Variable:		Grap' Price	S.E.	Grap' Price	S.E.
Independent Variable:					
Quantity	Israel	-0.0216	(0.0076)	-0.0790	(0.050)
Quantity	others	-0.0068	(0.0055)	-0.0455	(0.065)
Quantity	oranges	$-0.65 \cdot 10^{-3}$	$(0.95 \cdot 10^{-3})$	-0.0987	(0.085)
Quantity	easy-peelers	0.0013	(0.0010)	-0.0582	(0.028)
Quantity	Isr. oranges	-0.0011	(0.0027)	0.0114	(0.017)
Expenditures		$0.90 \cdot 10^{-4}$	$(0.78 \cdot 10^{-3})$	0.373	(0.128)
Trend		-2.17	(1.28)	-0.290	(0.072)
October		172.46	(29.61)	0.481	(0.131)
November		145.87	(29.55)	0.325	(0.122)
Season	1984/85	241.09	(54.60)	N.A.	N.A.
Freeze	1989/90	121.88	(63.49)	0.036	(0.061)
Share	White	-55.62	(253.20)	0.081	(0.144)
Constant		1141.7	(278.91)	2.985	(1.454)
R^2		0.82		0.72	
DW		1.91		1.62	

Once more, functional forms are chosen on the basis of explanatory power. For England we fitted a double logarithmic form and for Germany a linear demand function. In estimating the German demand function we corrected for first-order autocorrelation of residuals. The demand function for the English market was estimated using the two-stage least square method. Imports of grapefruit from Israel have a significant negative effect on prices of Israeli grapefruit in Germany. Nevertheless, the own price flexibility for import demand of Israeli grapefruit is quite small and equals -0.062 . The coefficient for import of grapefruits from competing countries shows the expected sign and is nearly significant at the 10% level for a one-sided t-test. In the case of import demand to England this coefficient is not significant but the coefficient for imports of grapefruit from Israel shows the expected negative sign and is significant at the 10% level for a one-sided t-test. The own price flexibility is similar to the one estimated for the German grapefruit market and equals -0.079 . The coefficient for orange quantities is not significant in both markets, suggesting that German and English grapefruit consumers do not view oranges as a substitute. The coefficients for quantities of easy peelers and expenditure for citrus are significant with the expected signs in the English market while not significant in the German market. The variables expenditure and easy peeler quantities are highly correlated, especially in the German market, therefore it is impossible to base further conclusions on these results. The coefficient for the trend variable is significantly negative for both markets, for the German market at the 10% level. This suggests, like in the orange markets, an adverse change in consumer preferences. Two dummies were incorporated to capture the special status that Israeli export enjoys in the first two months of the season. In this months the supply of grapefruit from other countries and substitute citrus fruits are both low. The "Freeze" dummy captures the effect of the widely spread freeze in Florida during December 1989, which led to a dramatic decrease in the export of Florida - an important supplier of European grapefruits markets. The season 1984/85 is characterized by unusual low supply of grapefruit as well as oranges. The variable representing the share of white grapefruit in Israeli grapefruit exports is not significant in both markets. Like in the orange market also the estimation results for grapefruit demand do not support the hypothesis of cross subsidization among varieties. The coefficients for Israeli orange imports are not significant

in both markets.

6. Estimating the Behavioral Relationships

An estimation of the behavioral equation (8) enables us to analyze if market power potential has been exploited. In 1993, with the elimination of customs among EC countries, the data collection method has changed. In our data we see unexplained deviation between the custom prices and the prices reported from wholesale markets, in the period after 1992, especially in England. Accordingly, for the estimation of the behavioral relationships, we employed observations till December 1992, only.

6.1 The Orange Market

In the case of the orange market the behavioral equation is:

$$s^{Et}p_o^{Et} - s^{Gt}p_o^{Gt} = \alpha^0 + \alpha^1 s^{Gt}q_o^{Gt} - \alpha^2 s^{Et}q_o^{Et} + \alpha^3 s^{Gt}q_{gr}^{Gt} - \alpha^4 s^{Et}q_{gr}^{Et} + \epsilon_o^t, \quad (11)$$

where as before, E stands for England, G for Germany, o for oranges and gr for grapefruits. A random disturbance is added in terms of a random variable ϵ^t with the usual assumptions: $E(\epsilon^t) = 0$, $V(\epsilon^t) = \sigma \forall t$ and $Cov(\epsilon^t, \epsilon^{t'}) = 0 \forall t, t'$. The constant is included in the equation in order to account for an eventual difference in price levels between both markets. A possible reason for such a difference are different transportation costs.

Table 3 reports the estimation results for the orange market.

Table 3: Behavior in Orange Market

<u>Dependent Variable:</u>	<u>$s^E P_o^E - s^G P_o^G$</u>	<u>Standard Error</u>
<u>Independent Variable:</u>		
Oranges Germany	0.001	(0.002)
Oranges England	$-0.9 \cdot 10^{-4}$	$(0.66 \cdot 10^{-3})$
Grapefruit Germany	0.006	(0.008)
Grapefruit England	-0.005	(0.004)
Constant	14.76	(12.1)
R^2	0.06	
Dw	1.99	

All the explanatory variables are statistically insignificant. Moreover, the simultaneous hypotheses that all coefficients are zero is also not rejected. We therefore fail to reject the hypothesis of competitive conduct by the CMBI in the orange market. It is left to examine the grapefruit market.

6.2 The Grapefruit Market

In the case of the grapefruit market the behavioral equation is:

$$s^{Et} p_{gr}^{Et} - s^{Gt} p_{gr}^{Gt} = \beta^0 + \beta^1 s^{Gt} q_o^{Gt} - \beta^2 s^{Et} q_o^{Et} + \beta^3 s^{Gt} q_{gr}^{Gt} - \beta^4 s^{Et} q_{gr}^{Et} + \epsilon_{gr}^t, \quad (12)$$

where the notations are as before. Table 4 reports the estimation results.

Table 4: Behavior in Grapefruit Market

Dependent Variable:	$s^E P_{gr}^E - s^G P_{gr}^G$	Standard Error
Independent Variable:		
Oranges Germany	0.0012	(0.0028)
Oranges England	$-0.11 \cdot 10^{-3}$	$(0.727 \cdot 10^{-3})$
Grapefruit Germany	-0.012	(0.013)
Grapefruit England	0.0014	(0.0042)
Constant	-28.6	(23.8)
R^2	0.09	
Dw	1.78	

Once more, all the explanatory variables are statistically insignificant and the simultaneous hypotheses that all coefficients are zero can not be rejected. These results imply that we fail to reject the hypothesis of competitive conduct by the CMBI, also in the grapefruit market.

The constants are expected to be close to zero because transportation costs to England and Germany are probably very similar. According to the estimation results we fail to reject the hypothesis that the constants are zero. The constant in the behavioral equation for oranges has a positive sign, while the constant in the case of grapefruits is negative. Probably the reason for this is that Israeli import prices for grapefruit in the German

market are slightly higher than in the English market because a higher share of imports is of the red, more expensive variety.

7. Simulation of Optimal Exporter's Behavior

The different demand flexibilities estimated in the German and in the English market for orange and grapefruit imports from Israel suggest that the CMBI had the possibility to increase export revenues by using third degree price discrimination but the scope to increase revenues is small because of quite elastic demand in both markets. In this section we simulate optimal behavior of the CMBI by equating marginal revenue in both export markets. The results show that the increase in export revenues is small. Table 5 reports the simulation results.

Table 5: Simulation Results

	<u>Oranges ($n = 62$)</u>	<u>Grapefruit ($n = 47$)</u>
Exports to England:		
Observed Quantity (mt)	468,644	107,143
Optimal Quantity (mt)	298,555	86,777
Exports to Germany:		
Observed Quantity (mt)	276,528	193,958
Optimal Quantity (mt)	446,617	214,344
Observed Revenue (Mio. NS)	381.2	181.6
Simulated Revenue (Mio. NS)	388.0	182.4
Increase in Revenue (Mio. NS)	6.8	0.8

For oranges, revenue would increase by 1.8 percent which is equivalent to 6.8 million New Shekel (NS) in the 47 months with import data for both markets (deflated to basis of 1986). This would be achieved by a reallocation of quantities from the market with lower elasticity of demand for Israeli oranges to the market with higher elasticity. Exports to England would decrease from 468,644 tonnes to 298,555 tonnes with a parallel increase in exports to Germany from 276,528 tonnes to 446,617 tonnes. Demand flexibilities estimated for Israeli grapefruit imports to England and Germany are quite similar and therefore a

relatively small adjustment of quantities is expected. Simulation results indicate a substantial reallocation of quantities from England, the market with slightly lower import demand elasticity for Israeli grapefruit, to Germany. Nevertheless, like expected, the reallocation of quantities is much smaller than in orange exports. In the 62 months with import data for both markets exports to England would decrease from 107,143 tonnes to 86,777 tonnes while exports to Germany would increase from 193,958 to 214,344 tonnes. The increase in revenue is less than one million New Shekel.

This results are just a rough estimate of the results of optimal price discrimination. We implicitly assume that other suppliers do not respond to the change in supplies of Israeli citrus fruit. It may be that the estimated residual demand equations do not adequately describe market demand any more because of the large change in quantities imported by each country.

8. Price Discrimination between Export Markets and the Local Market

Until March 1991 the CMBI had a monopoly position in the Israeli market for fresh citrus fruit. Fresh citrus consumption per capita in Israel is high - citrus and especially oranges are one of the main fruits consumed in winter months. Therefore it can be assumed that the demand for citrus fruit in Israel is quite inelastic with a large potential for exercising market power. It is possible that the CMBI did not exploit the limited potential for price discrimination between different export markets but nevertheless acted as a monopoly in the local market and exercised price discrimination between fruit exported and fruit sold in the local market.

This assumption is supported by a comparison of average seasonal FOB export prices for oranges and the revenue per ton oranges sold in the local market (Table 6). In average in the seasons 1986/87 until 1989/89, Shamouti and Valencia oranges were sold in the local market at a price premium of about 80 percent. The observed price premium differs substantially from season to season and for the two varieties.

Table 6: Orange Prices (Dollar/mt)

	Shamouti		Valencia Lates	
	<u>FOB Price</u>	<u>P' Loc. Market</u>	<u>FOB Price</u>	<u>P' Loc. Market</u>
1986/87	303	608	374	553
1987/88	359	723	288	707
1988/89	343	645	327	540
1989/90	340	494	389	536

Source: CMBI, 1989

The costs of growing, picking, packing and sending citrus fruit to the local market are about the same as the costs of growing and preparing fruit for export and sending it to the harbour. If export prices at the FOB level and wholesale prices in Israel are used we can assume that marginal costs for exporting and for supplying the local market are identical and use equation (8) to test for third degree price discrimination. Rearranging equation (7) without taking into account the possibility of cross subsidization among citrus varieties yields

$$\frac{p^L}{p^E} = \frac{\frac{1+\lambda^E}{\nu^E}}{\frac{1+\lambda^L}{\nu^L}}, \quad (13)$$

where E stands for export market, L for local market and ν is the price elasticity of demand. According to (13) higher prices can be expected in the market with the less elastic demand, in our case the local market. In addition, the equation shows that the relation between prices in both markets is constant as long as elasticities of demand and the λ 's are not changing. In the short run we can assume constant λ 's. Elasticities may be constant in the short run if there are just small moves along the demand curve. In reality, in citrus markets moves along the demand curve are frequent and quite large because of the seasonality of supply. Therefore the price relation between prices for exported fruit and prices for fruit sold in the local market is not constant. Nevertheless, highly correlated prices should be expected because the moves along the demand curves in both markets are always in the same direction if marginal costs for both markets are equal.

Unfortunately, not enough data on monthly FOB export prices for different citrus varieties are available to estimate the behavioral equation or to calculate price correlations. Therefore, consumer prices in Israel and unit values of importing countries (England and Germany) translated to the currency of the exporting country are used to calculate price correlations. Now, price differences reflect not just price discrimination between the local market and export markets but also differences in marketing costs. The additional cost components are mainly sea transportation for the exported fruit and wholesale and retail marketing margins for the fruit sold in the local market. These costs are just a small part of total costs occurred in producing and preparing the fruit for marketing. They generally change gradually and will probably lead just to minor distortions of the calculation results.

Estimation of correlation coefficients for prices of fruit exported to Germany and England and consumer prices of fruit sold in the local market show that the correlation between export prices and prices in the local market is very low in the period beginning with season 1985/86 until the liberalization of the local market in April 1991. The values of the correlation coefficients are between 0.10 and 0.32 ($r = 0.31$ for oranges exported

to Germany and sold in the local market, $r = 0.18$ for oranges exported to England and sold in the local market, $r = 0.10$ for grapefruit exported to Germany and sold in the local market, $r = 0.32$ for grapefruit exported to England and sold in the local market). Correlation coefficients calculated for export prices and wholesale prices in the local market are very similar. The price difference between prices in the local market and prices for fruit exported in the period from season 1985/86 until season 1989/90 far exceeds the price difference in the period after liberalizing the local market. This evidence suggests that the CMBI exploited its monopoly power in the local market by using price discrimination between the local market and export markets but it did not behave in an optimal profit-maximizing way.

9. Summary and Conclusions

The paper proposes a methodology to test for monopolistic pricing by a multiproduct multimarket firm. The application of this methodology to the German and English markets for Israeli citrus shows that the CMBI as a centralized export institution had little scope to exploit its organizational structure to elevate revenues in export markets. Import demands for Israeli oranges and grapefruits in both England and Germany are quite elastic and provides a very limited potential for exploiting monopolistic market power to increase export revenues. Moreover, although *a priori*, one may think that the demands for grapefruits and oranges are interdependent, little evidence to support this hypothesis is found.

The findings suggest that the demand for Israeli oranges in England is less elastic than the analogous German demand. Also the demand for Israeli grapefruits in England is less elastic than the corresponding German demand but the difference is quite small. These findings are consistent with, previously published, studies of consumer preferences in the two countries and differences in market share between both markets. The above results imply that the CMBI could employ third degree price discrimination between the German and English markets. Nevertheless, the estimation of the behavioral equations shows the CMBI did not exploit this potential.

To summarize, we find that as a sole exporter of Israeli citrus the CMBI enjoyed large market shares and wide awareness by consumers of the Israeli citrus brand "Jaffa".

However, we fail to reject the hypothesis that its market conduct is competitive. On the one hand, these results question the claim of supporters of centralized exporting as a mean to increase growers revenues. On the other hand, the results are encouraging for advocates of free international trade.

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Description of Cooperation

Cooperation was facilitated mainly by several meetings of the investigators. Professor Buccola, Dr. Bar-Shira, and Dr. Finkelshtain have met during the summer of 1994 in San Diego where they summarised the first year of the project and outlined the continuation. Professor Buccola visited with Dr. Bar-Shira and Dr. Finkelshtain for the summer of 1995, and Dr. Bar-Shira visited with Professor Buccola in the beginning of 1996. These two meetings have been utilised for comparisons and mutual feedback regarding the theoretical and empirical parts conducted in Oregon and Israel.

Evaluation of Research Achievements

This research extends the literature regarding processing and marketing of agricultural products. Special emphasis is given to technological, organisational, and behavioural aspects of marketing systems. We develop theoretical frameworks, oriented at characterisation of optimal marketing structure, which place wide foundation for empirical studies. Our empirical applications, although not fully exploit the potential of the theoretical basis, allow quantification of advantages and disadvantages of specific marketing system. The applicable recommendation is that neither complete pooling in processing and marketing institutions nor pure competitive is optimal, however some mixture of the two might be.

List of Publications

- Bar-Shira, Ziv, Israel Finkelshtain, and Eithan Hochman. "Farmers Response to Component Pricing: a Nonparametric Approach." Presented at the Annual Meeting of the *American Agricultural Economics Association*, Atlanta, Georgia, August 1995.
- ✓ Bar-Shira, Ziv and Israel Finkelshtain. "Nonparametric Analysis of Pooled Production Data." *Economic Letters*. 55(1997) 173-78.
- ✓ Bar-Shira, Ziv and Israel Finkelshtain. "Simple Non-Parametric Tests of Technological Change: Theory and Application to U.S. Agriculture." In revision to *American Journal of Agricultural Economics*. 1998.
- Bar-Shira, Ziv and Israel Finkelshtain. "The Long-Run Inefficiency of Block-Rate Water Pricing." Will be Presented at the Annual Meeting of the *American Agricultural Economics Association*, Salt Lake City, August 1998.
- ✓ Ben-Adiva Daniel. "Hedonic Pricing as an Instrument for Profit Maximisation in the Cotton Industry: Parametric and Nonparametric Approaches." A Master Thesis, Ben-Gurion University, Beer-Sheva, Israel. (Hebrew) 1994.
- ✓ Buccola, T. Steven and Jayashree Sil. "Productivity Measurement in the Agricultural Marketing Sector." *American Journal of Agricultural Economics*. 78(1996) 1366-71.
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