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Chile's agricultural diversification

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ABSTRACT

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Chile's fruit sector, both in production and exports, has grown significantly since 1974. At that time, Chile introduced structural reforms in its economy which assured that market principles would operate regarding land ownership. Also, the government began a 'hands-off' policy which basically allowed free-market principles to prevail. As a result of these conditions operating in the economy, Chile's agricultural sector diversified from producing largely annual crops and wool to also producing a significant amount of commercial fruit crops. A second round of diversification is currently underway within the fruit industry where pears and peaches are being produced and exported in addition to apples and table grapes.

In this paper we derive decision criteria when aggregate performance is evaluated from the perspective of maximizing a risk-averse utility function. Empirical evidence on Chilean fruit exports indicates that, on an aggregate level, Chilean fruit exporters are following the path of utility maximization and validates the sequence by which Chilean producers introduced nontraditional crops over time. While on an individual level there may be complex factors and constraints involved in the planting decisions, the results of this study seem to indicate that the sum of producer behavior satisfies the conditions required for maximizing a risk-averse utility function.

INTRODUCTION

Chile's fruit sector, both in production and exports, has grown significantly since 1974. Chile is considered a model by other Latin American countries which seek to diversify their agricultural sectors, and its experience is worth exploring (Arnade and Lee, 1990).

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From the mid 1960's until 1973, Chilean government policies regarding land reform and consequently land expropriations were somewhat discretionary. There was minimal security of property rights and, as a result, farmers made few long-term investments in perennial crops. Agricultural production centered on several annual crops and wool.

However, beginning in 1974 structural reform was implemented. Producers received assurances that market principles would operate regarding land ownership which allowed agriculture to become attractive for long-term investments. Also, the government began a 'hands-off' policy which basically allowed free-market principles to prevail. As a result of these conditions operating in the economy, Chile's agricultural sector diversified significantly as firms began large-scale investment in fruit tree plantings. Given Chile's natural endowments fruits can be grown at competitive costs.

The aggregate response in the agricultural sector to the economic conditions prevailing since 1974 has been accelerated growth and increasing diversity. The Chilean economy is stronger and more resiliant as a result. Previous to 1974 Chile's primary agricultural exports were legume crops and wool. After 1974 Chile also began exporting large quantities of apples and table grapes. By the early 1980's Chile's agricultural exports were heavily concentrated in these two crops. Another round of diversification is currently underway. This second round is a response to being an economy which is heavily dependent upon exports. Due to this, Chile is now sensitive to world prices for its fruit crops. Consequently, there is incentive to diversify in order to lessen the negative impacts of a drop in the price of one or more of Chile's significant crops. Farmers are moving into production of pears, peaches, nectarines, and stone fruit. Exports of these products are expanding (Sparks and Bravo-Ureta, 1991).

Figure 1 plots indices of concentration for Chilean agricultural export products. The index represents the sum of the square of the shares of export values in each category multiplied by 100. If only one agricultural good is exported this index equals 100. The greater the diversity of exports, the closer this index lies to zero. [1] From 1962 to 1977 the indices show that Chile's agricultural exports were gradually becoming less concentrated. By 1978 the index begins rising, reflecting Chile's increasing concentration of apple and table grape exports. The highest level of concentration was observed in 1985. After that time Chile's exports of pears, peaches and nectarines rose significantly and the concentration index fell.

[1] The concentration index is defined as: $100 * \Sigma_i (x_i / \Sigma_i x_i)^2$, where x_i is the value of exports of good i.

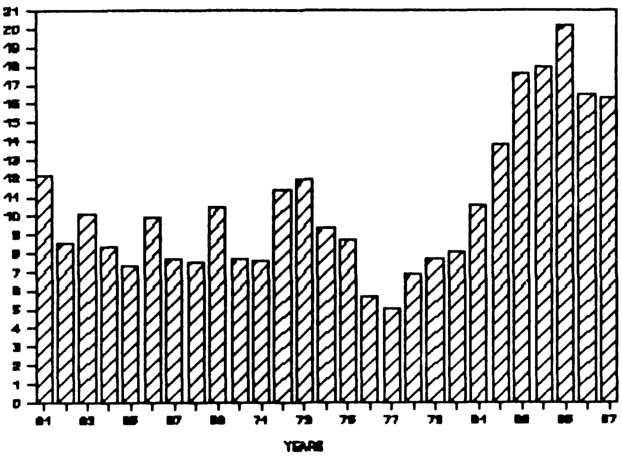

Fig. 1. Index of concentration of Chile's agricultural exports.

Table 1 presents the coefficients of variation (cv's) of free on board (FOB) export prices for Chile's major agricultural exports. Also reported are the value agricultural exports earned from each of the commodities relative to the value of bean exports. Relative cv's for apples and table grapes were low in the 1960's but in the later time periods they grew remarkably large, indicating a possible reason for the recent move to diversify fruit production and exports.

In the following section we derive the decision criteria when exporters (or producers) move from maximizing profits to maximizing a risk-averse utility function and prices are stochastic. We then apply these criteria to data on Chilean fruit exports to ascertain whether the path of diversification being followed in Chile is consistent with utility maximization.

The decision criteria are broad enough to be applied to individual producers, exporters, or lenders. The later two decide what mix of products to export (or lend to) in the country at large. We justify analysis at the aggregate level by assuming the existence of an aggregate welfare function. Individual decisions may be based on similar utility functions or not. In fact, there may be many constraints operating on individual producers which effectively restrict their choices regarding diversification. Yet, whatever the reasons behind individual decisions, we will show that the sum of exporter or producer behavior meets the criteria for maximization of an aggregate risk averse utility function.

It is important to note that the identified traditional crops in Chile are not directly competitive with apples and table grapes for land resources. They are grown in different regions. If the move into fruit crops is evaluated in terms of the advantages of a diversified agricultural portfolio

TABLE 1

Relative coefficients of variation of major Chilean agricultural exports

	Price cv's	Relative agricultural exports
	1962 to 1967	
Beans	1.36	1.00
Apples	0.19	0.91
Table grapes	0.86	0.68
Wool	19.54	2.90
Lentils	5.50	0.65
	1968 to 1973	
Beans	55.48	1.00
Apples	9.82	1.32
Table grapes	4.45	1.61
Wool	NA	3.14
Lentils	27.62	0.40
	1974 to 1987	
Beans	33.00	1.00
Apples	12.03	3.53
Table grapes	67.99	5.70
Wool	44.28	0.97
Lentils	27.71	0.39

Prices are represented by Chile's export unit values. Due to missing data, cv for wool prices from 1968 to 1973 are not available.
Data source: FAO Trade Yearbook and U.N. trade data.

rather than from the standpoint of maximizing profits (and/or export earnings) fruit crops may be considered complementary to the traditional crops.

UTILITY MAXIMIZATION

Assume a profit maximizing solution lies in the corner of a constant cost frontier [2]. The produced good is called the traditional good and the nonproduced good is called the nontraditional good (Fig. 2). Assume that relative costs are such that a rise in price of the nontraditional product leads to an interior solution on the same or higher frontier.

[2] The constant cost frontier represents a continuous combination of outputs that result in a multioutput cost function equal to some constant C.

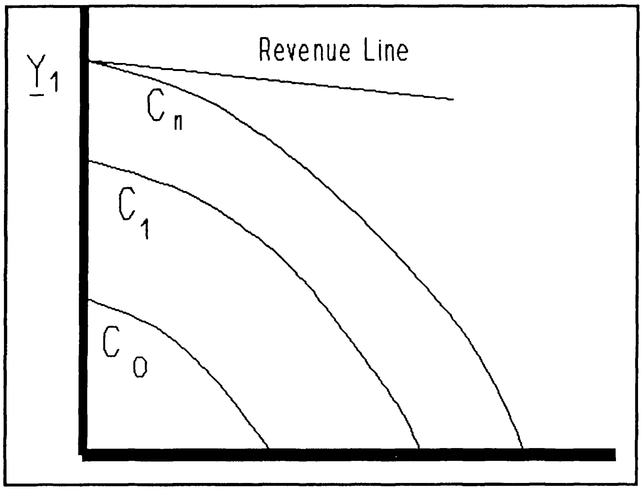

Fig. 2. Corner solution on constant cost frontier.

Arnade and Lee (A&L, 1990) demonstrated a necessary (but not sufficient) condition for a nontraditional crop to be grown when relative crop prices do not change and producers move from maximizing profits to maximizing a risk-averse utility function. A key limitation of the A&L paper is its assumption of a two-good world where one crop is considered traditional and the other nontraditional. The two-good case may be suitable for producers; however, exporters, lenders, or analysts concerned with evaluating aggregate welfare would take into account the diversity of crops in the country at large. Therefore it would be useful to generalize to *n* crops the conditions in which exporting (or producing) an additional crop will increase a utility function which takes into account profits and risk.

Represent an aggregate agricultural welfare function as a linear combination of the first two moments of the distribution of income. To maximize welfare one solves:

$$\text{MAX } E(\pi) - \phi * \sigma_{\pi}^{2} \tag{1}$$

where π represents income, E is an expectation operator, σ_{π}^{2} represents the variance of income, and ϕ represents a coefficient of risk aversion.

The function to be maximized in equation (1) was introduced by Tobin (1958), Levy and Markowitz (1979) and Friedman and Savage (1969) to represent the utility of risk-averse agents. Though used primarily in finance, maximization of expected profit less variance (E–V analysis) has been adopted to agricultural issues (Dubman et al., 1988; House, 1983; Musser et al., (1980). Despite criticism by Lambert and McCarl (1985) and Taylor (1986), this function remains widely used in depicting preferences.

Assume prices are stochastic and output is known. Under these conditions, the expected income is written as:

$$\mathrm{E}(\pi) = \sum_{i=1}^{n} p_i Y_i - C(W, Z, Y_1, Y_2, \ldots, Y_n) \tag{2}$$

where p_i represents the expected price of output i, the outputs Y_i are choice variables, W is a vector of input prices, Z is a fixed input, and $C(W, Z, Y_1, Y_2, \ldots, Y_n)$ represents a multi-output cost function. [3]

Substituting for income in equation (1):

$$\text{MAX} \sum_{i=1}^{n} P_i Y_i - C(W, Z, Y_1, Y_2, \ldots, Y_n) - \phi * \sigma_\pi^2 \tag{3}$$

For the n-good case, the variance of income, σ_π^2 is represented as:

$$\sigma_\pi^2 = \sum_{i=1}^{n} \sum_{j>i}^{n} 2 \operatorname{cov}(P_i, P_j) Y_i Y_{j'} + \sum_{i=1}^{n} \operatorname{var}((P_i) Y_i^2) \tag{4}$$

where $\operatorname{cov}(P_i, P_j)$ refers to the covariances between the prices of good i and good j and/or the price variance of good i.

The n first-order conditions for the utility-maximization problem result from taking the derivative of (3) with respect to Y_i:

$$P_i = \partial C(\cdot)/\partial Y_i + \phi \left[2 \operatorname{var}(P_i) Y_i + \sum_{j=1}^{n} 2 \operatorname{cov}(P_i, P_j) Y_j \right] \tag{5}$$

where $\partial C(\cdot)/\partial Y_i$ is the marginal cost with respect to Y_i and $i, \ldots, n$. [4]

Suppose the nth crop had not been grown in the past and is called a non-traditional crop. The relative FOC conditions of the nontraditional crop to the ith crop can be written as:

$$(P_n - \phi W_n)/(P_i - \phi W_i) = [\partial C(\cdot)/\partial Y_n]/[\partial C(\cdot)/\partial Y_i] \tag{6}$$

where

$$W_n = 2\left[\operatorname{var}(P_n) Y_n + \sum_{i=1}^{n} \operatorname{cov}(P_n, P_j) Y_j \right]$$

and

$$W_i = 2\left[\operatorname{var}(P_i) Y_i + \sum_{i=1}^{n} \operatorname{cov}(P_i, P_j) Y_j \right]$$

[3] If production is non-joint, equation (3) consists of individual cost functions.

[4] If the coefficient of risk aversion (ϕ) is zero, equation 5 collapses to the typical profit maximizing first-order conditions.

It was assumed that the profit maximizing solution was just in the corner of a multidimensional constant-cost frontier so a rise in any P_n/P_i justifies an interior solution. Therefore if the ratio of the prices with the additional variance terms is greater than the ratio of the prices, for any ith crop, exporting (or producing) the nontraditional crop can be justified. This condition for any of the $n-1$ i-terms is:

$$(P_n - \phi W_n)/(P_i - \phi W_i) > (P_n)/(P_i) \qquad \text{for } i = 1, \ldots, n-1 \tag{7}$$

Evaluate equation (7) from the point when the decision to diversify is made. The terms in W that include non-traditional crops (whose output is initially zero) drop out. Call ${}^2W_1$ and ${}^2W_2$ the W terms for goods 1 and 2 where the superscript 2 indicates that export (production) of good 2 is zero. The ${}^nW_1$, ${}^nW_2$-terms for goods 1, 2 represent the W's when only Y_n equals zero. Using this notation equation (7) can be written as:

$$(P_n - \phi^n W_n)/(P_i - \phi^n W_i) > (P_n)/(P_i) \tag{8}$$

for any i. Substituting in for ${}^nW_n$ and ${}^nW_i$, condition (8) can be rearranged as:

$$\left[P_n - \phi\left(\sum_{j=1}^{n-1} 2Y_j \operatorname{cov}(P_n, P_j)\right)\right]/P_n \tag{9}$$

$$> \left[P_i - \phi\left(\sum_{j=1}^{n-1} 2Y_j \operatorname{cov}(P_j, P_i) + \operatorname{var}(P_i)\, 2Y_i\right)\right]/(P_i)$$

Dividing by the P terms, rearranging, multiplying through by -1, condition (9) is equivalent to: [5]

$$P_n/P_i > \left[\sum_{j=1}^{n-1} Y_j \operatorname{cov}(P_n, P_j)\right] \Big/ \left[\sum_{j=1}^{n-1} Y_j \operatorname{cov}(P_i, P_j) + \operatorname{var}(P_i)\, Y_i\right] \tag{10}$$

When there are only two goods, a nontraditional good n and traditional good i, this condition reduces to: [6]

$$P_n/P_i > [\operatorname{cov}(P_i, P_n)]/[\operatorname{var}(P_i)] \tag{11}$$

[5] Condition (10) can hold even when there are positive covariances between output prices of traditional and nontraditional crops. This case makes plain that, if relative prices are high enough, even risk-averse producers can increase utility by choosing crops that are not counter-cyclical.

[6] By assuming stochastic output and known prices, an analogous condition can be derived. For example, in the two good case, if output is stochastic, comparision of utility maximization with profit maximization will show production of nontraditionals will increase utility if: $T_n/T_1 > P_n/P_1$, where T_n is the change in the variance of cost with respect to output. If policy instability can be linked to export instability, and, if data were available, this condition could be tested to see if it would explain the first round of diversification.

TABLE 2

Two output criteria (equation 11)

	Apples with:		
	Beans	Lentils	Wool
1961–65	−0.16	−0.22	0.20
1967–73	0.28	0.84	0.00
1974–79	−0.54	−0.24	−0.33
	Table grapes with:		
	Beans	Lentils	Wool
1961–65	−0.64	0.32	−0.50
1967–73	0.24	0.55	0.00
1974–79	−0.16	0.91	0.12

The numbers in this table represent the covariance-to-variance ratio to the relative price ratio. If the number is less than 1, then condition (11) holds.

Equation (11) is A&L's required condition for expansion into a nontraditional when there are two crops. If conditions (10) or (11) hold, the necessary condition for increasing utility by producing or exporting the nontraditional crop holds. We now investigate whether these diversification criteria have held during the periods when Chile diversified its fruit exports.

EMPIRICAL APPLICATION TO THE CHILEAN EXPERIENCE

As noted earlier, Chile's diversification of agricultural exports happened in two stages. In the 1970's exports of apples and table grapes expanded as economic stability enabled producers to make long run investments. These exports supplemented and then came to dominate traditional exports. In the second stage of diversification, which is still occurring, Chilean producers have also moved into the export of pears and peaches.

Implementation of conditions (10) and (11) yields insight as to whether the utility maximizing criteria were met when Chilean producers expanded into new products. Table 2 presents the two output criteria for apples and grapes with each traditional crop individually (equation 11). [7] For both fruit crops, in each of three time periods, the criteria are met. Aggregate utility is increased by exporting apples and table grapes. Table 3 presents the multi-output criteria (condition 10) for each of apples and table grapes. In this criteria the existing diversity of exports, in the country at large, is

[7] The intermediate steps in the calculation of each diversification criteria are presented in an expanded version of this paper.

TABLE 3

Multi-output criteria (equation 10)

	Multi-output apples to:		
	Beans	Lentils	Wool
1961–65	1.87	1.34	0.37
1974–79	4.00	3.53	1.91
	Multi-output table grapes to:		
	Beans	Lentils	Wool
1964–65	−2.00	−1.43	−0.40
1974–79	7.37	6.51	3.52

The numbers in this table represent the right hand side over the left hand side of equation (10). If the terms are less than 1, the criteria for growing the non-traditional crop is met.

taken into account. Both apples and table grapes meet the conditions required for increasing utility in the 1961–1965 time period but not for the 1974–1979 time period. [8] This last result indicates a motive for the second round of diversification into peaches and pears.

Table 4 presents the results of applying the two-good world criteria to pears and peaches against the already produced crops for the period 1974–1979. For both peaches and pears the criteria for increasing utility by diversification is met. Since by the late 1970's Chile's agricultural exports were dominated by apples and table grapes, the conditions in the two far right columns of Table 4 are most relevant. Though the prices of pears and peaches are positively related to the prices of apples and table grapes, and they are not countercyclical crops, they still meet the criteria for expansion.

Table 5 presents the results of applying the multi-crop criteria to pears and peaches. This analysis, which takes into account existing crop diversity, only holds against apples and table grapes. Exporting peaches and pears is

TABLE 4

Two output criteria, 1974–1979 (equation 11)

	Beans	Lentils	Wool	Apples	Table grapes
Pears	−0.40	0.93	−0.04	0.81	0.66
Peaches	−0.30	0.57	−0.03	0.60	0.45

The numbers in this table represent the covariance-to-variance ratio to the relative price ratio. If the number is less than 1, condition (11) holds.

[8] Data for wool exports are not available for the 1967–1973. To keep all empirical measures comparable, the multi-output criteria for this time period are not calculated.

TABLE 5

Multi-output criteria, 1974–1979 (equation 10)

	Beans	Lentils	Wool	Apples	Table grapes
Pears	4.39	3.88	2.10	1.10	0.60
Peaches	3.16	2.79	1.51	0.79	0.43

If any number in the table is less than 1, then the requirements for growing the new non-traditional holds.

justified only once apples and table grapes are established. This result verifies that the sequence by which nontraditional crops were chosen is consistent with maximizing a risk-averse utility function.

FURTHER DIVERSIFICATION CRITERIA UNDER UTILITY MAXIMIZATION

Suppose we compare utility maximization with n crops to utility maximization with $n+1$ crops, where $n+1$ becomes the new nontraditional crop. Assume once a crop is chosen it will be grown each year. Arrange the crops in numerical order of diversification so that 1 is the traditional crop, 2 represents the first step of diversification and 3 the second and so on. Addition of a new crop Y_n will increase utility if for any i the following condition holds:

$$(P_n - \phi W_n)/(P_i - \phi W_i) > (P_n - \phi^n W_n)/(P_i - \phi^n W_i) \tag{12}$$

where the notation is similar to the previous section. Equation (13) can be written as:

$$[P_n - \phi^n W_n - 2\,\mathrm{VAR}(P_n)\, Y_n]/[P_i - \phi^n W_i - 2\,\mathrm{COV}(P_i, P_{n-1})\, Y_n] > (P_n - \phi^n W_n)/(P_i - \phi^n W_i) \tag{13}$$

Canceling terms, rearranging dropping 1 and mutiplying through by negative 1, equation (13) can be shown to be: [9]

$$(P_n - \phi^n W_n]/(P_i - \phi^n W_i] > [\mathrm{VAR}(P_n)]/[(\mathrm{COV}(P_i, P_n)] \tag{14}$$

for any i.

Condition (14) is the required condition for exporting (growing) a new nontraditional crop Y_n when comparing two utility maximizing decisions. [10] The only distinction between the two decisions is that in one output Y_n is

[9] Equation (13) can rearranged as:

$$1-[\phi\, 2\,\mathrm{VAR}(P_n)\, Y_n]/[(P_n - \phi^n W_n)] > 1-[\phi\, 2\,\mathrm{COV}(P_i, P_n,)\, Y_n]/[(P_i - \phi^n W_i)]$$

Dropping the 1's, multiplying through be -1 and rearranging will produce condition (14).

[10] Note that the placement of variance and covariance is reversed from their locations in the profit versus utility maximization criteria.

TABLE 6

Utility MAX versus utility MAX (equation 14)

	$\phi = 1$	$\phi = 0.75$	$\phi = 0.5$
Pears to:			
apples	0.65	0.28	−254.91
grapes	1.52	1.83	221.16
beans	2.21	5.07	1999.53
lentils	−4.68	−0.66	−5662.47
wool	6.89	−17.94	−6088.07
Peaches to:			
apples	0.75	0.33	−296.38
grapes	1.93	2.33	280.51
beans	2.59	5.93	2338.38
lentils	−6.40	−0.90	−7740.95
wool	8.27	−21.52	−7302.86

The numbers in this table represent the right hand side over the left hand side of equation (14). This number must be less than 1 for at least one crop for the risk aversion criteria to hold. In this table and all tables where table grapes are referred to in a column on the left, in order to save space, grapes refers to table grapes.

taken in account and in the other it is not. Unlike the previous section, equation (14) in not evaluated at the point were the new non-traditional crop is zero. It follows that exporters (producers) would forecast Y_n since apriori they do not know what output will be.

To evaluate condition (14) we took the average of the export levels for each of the commodities from 1974 through 1979, the time period during which the decision was made. Unfortunately condition 14 is a function of the coefficient of risk aversion which often is unknown and must be estimated or parametrically varied. We chose three values for the coefficient of risk aversion, 1.0, 0.75, and 0.50.

Table 6 presents the results of the empirical evaluation of the decision criteria for pears and peaches against each of the traditional crops and most importantly, apples and table grapes. For both pears and peaches, at each level of risk aversion, diversification criteria are met when compared against apples and lentils. By 1980 lentils had a insignficant market share of traditional crops and can be ignored. Therefore, only once apples were exported would there be an incentive for exporters who are already maximizing a risk averse utility function (equation 14) to diversify into peaches and pears.

CONCLUSIONS

In this paper we considered Chilean agricultural export diversification decisions from the perspective of maximizing a utility function which takes into account *both* the profits and risks associated with an enterprise. This perspective reflects that of countries that consider Chile a model and is justified given the high price instability associated with traditional crops. Diversification decision criteria were derived based on movement away from profit maximizing behavior to utility maximizing behavior. Criteria are derived for a two-good world and for a multi-output world, which takes into account existing diversity in the country at large.

Empirical application of the decision criteria indicates that, on an aggregate level, Chilean fruit exporters are following the path of utility maximization. While on an individual level there may be many complex factors and constraints involved in the planting decisions, the sum of producer behavior satisfies the conditions required for maximizing a risk-averse utility function. The process by which diversity and thus aggregate welfare rises when summing the behavior of individual producers needs to be further explored. In some cases economic development even leads to specialization at the individual firm level, but remarkably, leads to increased diversification at the national level.

The first diversification into apple and table grape exports was partially a response to structural changes in the economy. Ex ante, it is doubtful that policy makers envisioned that long run economic stability would lead to such diversification and growth of the fruit sector in Chile. The second or current round of diversification, into pears and peaches, was justified when either producers (exporters) switch from maximizing profits to maximizing utility or when exporters (producers) compare two utility maximizing criteria. The increase in exports of pears and peaches appears to be a response to the high concentration of production in apples and the high variability of apple prices. Therefore this paper validates the sequence by which Chilean producers introduced nontraditional crops over time.

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