Evaluation of Marketing Instruments for Coffee Production in Veracruz: Implementing Stochastic Dominance with Limited Data

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Risk has traditionally been a significant consideration in agricultural production. This paper demonstrates how stochastic dominance can be applied to make production decisions under risk. The procedure is demonstrated using crop data from North Florida. Given this example, the paper then disusses how similar data can be constructured to make marketing decisions for coffee in Veracruz. Finally, the paper develops different dimensions of the coffee marketing problem. Specifically, the paper focuses on the benefits of storage along with the combination of cash and futures marketing instruments.

keywords: stochastic dominance, marketing decisions, coffee

1. Introduction

Historically, risk has been considered an endemic part of agricultural production. Historical references frequently refer to yield variations caused by natural factors such as droughts, pestilence, and floods. More recently, however, the economic consequences of open markets and currency devaluations have increased the importance and frequency of price variations for producers. The historical references can be classified as production risk while the more recent manifestations can be generalized as price risk. Within this general classification scheme, the producer has several alternatives for coping with each type of risk. Production risk can be controlled with agronomic practices such as variety selection, fertilizer decisions, etc. Marketing through alternative marketing instruments such as forward contracting, hedging, or the use of options can be used to control price risk within a given crop. Alternatively, diversification into other crops or livestock activities could be used to mitigate risk at the whole farm level. This paper examines alternative economic approaches for analyzing the control of price risk by coffee producers in Vera Cruz.

2. Theoretical Approaches to Decision Making Under Uncertainty

The traditional economic approach to decision making under risk is to assume that producers choose the alternative that maximizes their expected utility. However, the approach has its detractors. Most of the objections are linked to the lack of transitivity in utility ordering (Fishburn). The debate over transitivity along with subtle issues surrounding the estimation of risk aversion coefficients has led to the development of risk efficiency crite-

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ria such as stochastic dominance (Hadar and Russell). In general, a risk efficiency criteria is a decision rule that reduces the set of all feasible alternatives by eliminating those decisions that imply higher risk without an increased return. In this section, I develop the theoretical framework of first and second-degree stochastic dominance.

Following Hadar and Russell, I assume that the decision-maker has a utility function $U(x)$ defined on the outcomes of some random variable, x. Next, assume that the decision-maker will choose between two possible actions a_1 and a_2. The returns of random variable x under action a_1 are defined by the probability density function f while the returns of under action a_2 are defined by the probability density function g. For explanatory purposes, table 1 presents the returns per acre for production in Jefferson County, Florida. Figure 1 presents the probability density functions for the net return of corn and soybeans in Jefferson County. Let a_1 be planting corn and a_2 be planting soybeans. The choice of whether to plant corn or soybeans becomes a choice between the probability density functions in Figure 1.

Table 1. Net Returns per Acre for Agriculture in Jefferson County, Florida

	Corn	Soybeans	Cotton	Peanuts
1972	84.03	28.06	167.33	640.99
1973	277.63	189.35	469.34	666.89
1974	369.19	452.77	110.14	1,064.03
1975	135.40	182.15	66.12	1,255.71
1976	257.70	312.89	513.01	768.88
1977	-42.13	155.45	38.69	695.48
1978	87.66	143.37	250.90	940.96
1979	167.55	219.17	243.76	812.20
1980	253.16	160.89	543.11	625.64
1981	111.21	85.49	215.38	665.27
1982	95.70	75.74	218.27	507.90
1983	209.18	149.81	335.42	341.21
1984	90.95	21.73	392.06	650.46
1985	51.80	51.21	62.13	304.89
1986	-63.01	-10.85	98.37	389.77
1987	2.97	-17.82	111.20	412.07
1988	10.10	111.90	-117.42	410.29
1989	58.36	-21.09	-49.11	204.23
1990	18.43	-51.67	-14.10	310.63
1991	39.39	-9.25	-8.99	317.47
1992	-11.36	-25.24	-37.62	181.70
1993	-44.38	-43.28	49.66	63.70
1994	28.12	-28.00	-62.63	93.74
1995	79.69	-58.07	142.36	156.63
1996	110.20	59.58	-22.45	38.12
1997	-9.31	-9.13	-66.18	78.78

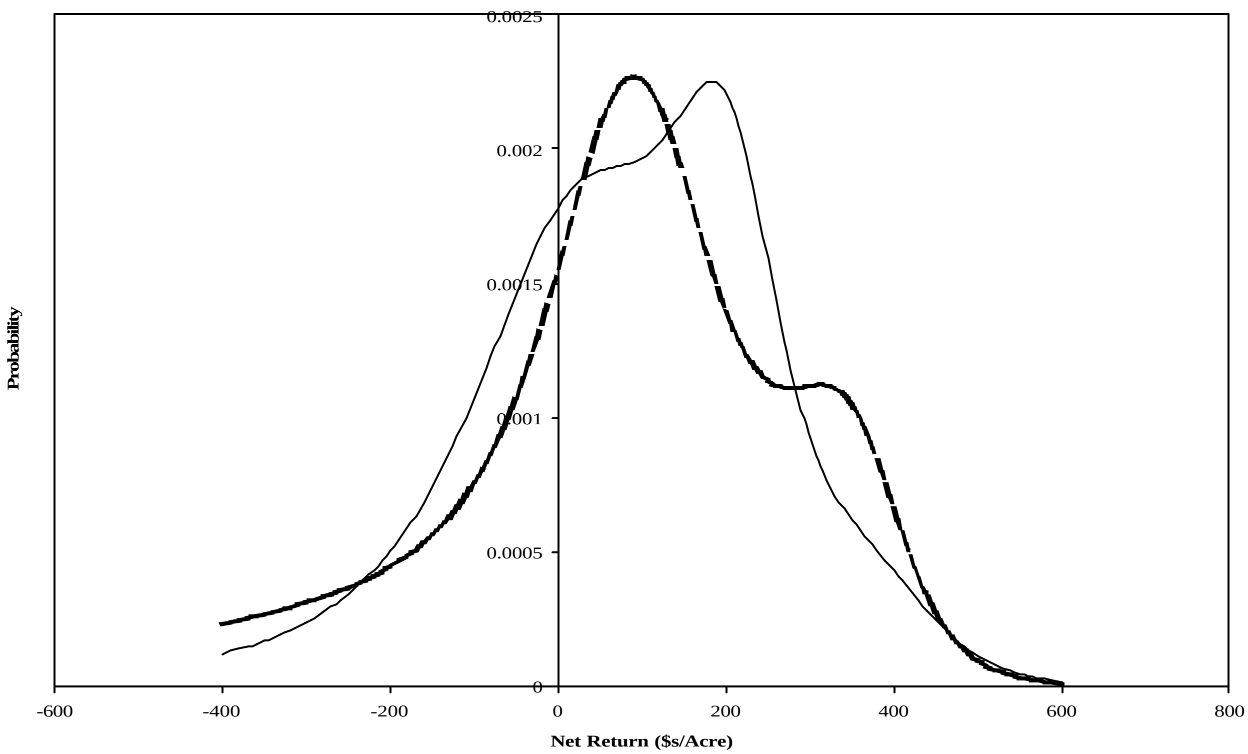

Figure 1. Probability Density Functions for Net Returns per Acre for Corn and Soybean Production in Jefferson County.

Corn dominates soybean production in the first degree if:

$$\Delta = E_F U(x) - E_G U(x) = \int_a^b [f(x) - g(x)] U(x) dx \geq 0 \quad (1)$$

for all x in the range x in (a,b) with at least one strict inequality. One interpretation of equation (1) is that corn will be preferred to soybeans if it is always expected to yield at least the same level of income with greater probability of earning a higher level of income for at least one income level. Integrating equation (1) by parts yielding then derives the rule for first degree stochastic dominance:

$$\Delta_1 = \left(U(x)[F(x) - G(x)] \right|_a^b + \int_a^b [G(x) - F(x)] U'(x) dx \quad (2)$$

where *F(x)* and *G(x)* denote the cumulative density functions for *f(x)* and *g(x)* respectively. The first term in equation (2) goes to zero since the cumulative density functions *F(x)* and *G(x)* are both equal to zero at *a* and one at *b*. Hence, by assuming that *U'(x)* is greater than zero for all levels of net return, then corn is preferred to soybeans if:

$$\tilde{\Delta}_1 = G(x) - F(x) \geq 0 \quad \forall \quad x \quad (3)$$

with at least one strict inequality. Figure 2 depicts the cumulative density functions for corn and soybeans in Jefferson County. For these two alternatives, neither crop dominates the other in the first degree. However, as figure 3 indicates, peanut production does dominate cotton production in the region.

Intuitively, first degree stochastic dominance is a fairly weak criterion, or eliminates relatively few decision alternatives. Second degree

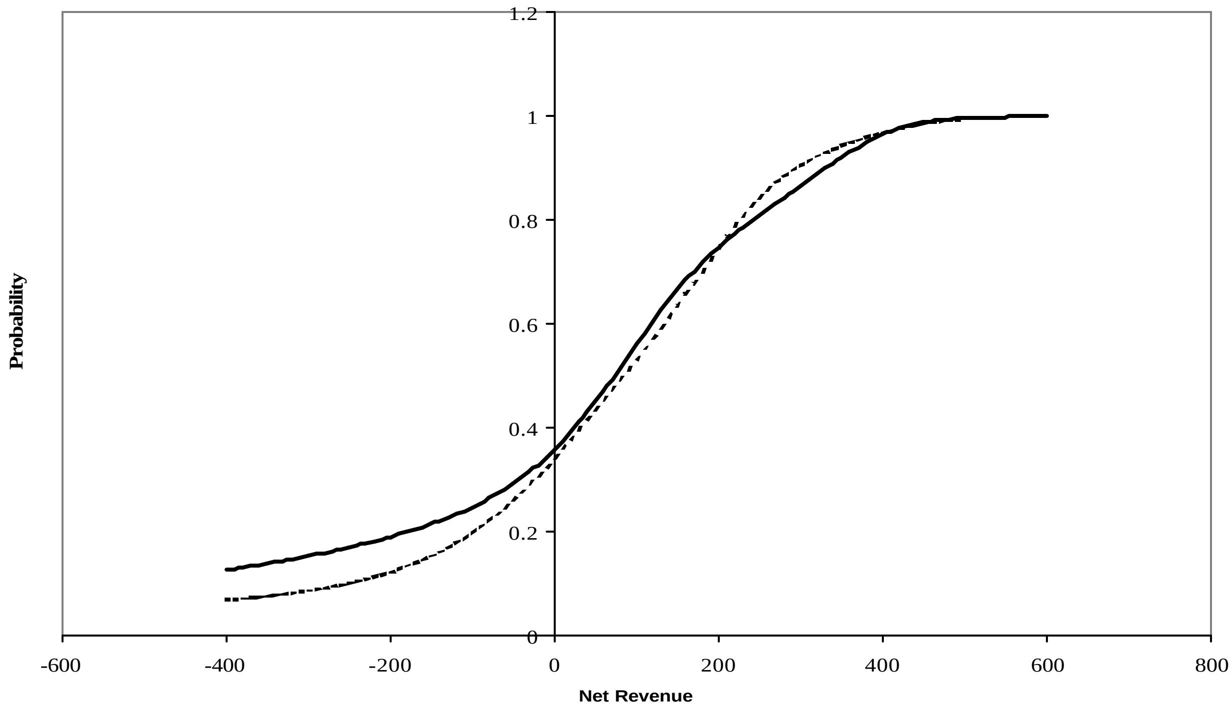

Figure 2. Cumulative Density Functions for Net Returns per Acre for Corn and Soybean Production in Jefferson County

stochastic dominance is somewhat more restrictive. Specifically, building on equation (2) we have

$$\Delta_2 = \left(U'(x) \int_a^b \left[G(x) - F(x) \right] dx \Big|_a^b + \int_a^b \left(-U''(x) \int_a^x \left[G(z) - F(z) \right] dz \right) dx \right) \quad (4)$$

which is positive if $U''(x)$ is negative and

$$\tilde{\Delta}_2 = \int_a^x \left[G(z) - F(z) \right] dz \geq 0 \quad \forall \quad x \quad (5)$$

with at least one strict inequality. The restriction on the derivatives of the utility function translates to any degree of risk aversion. Intuitively, this criterion implies that the area under the cumulative density function for f is always less than the area under the cumulative density function for g. Figure 4 depicts the value of equation (5) for corn and soybeans. The value is positive for all x thus corn dominates soybeans in the second degree.

Decision making under risk using stochastic dominance then involves elimination of actions that are dominated by another alternative in the first degree. This implies solving a sequence of binary comparisons:

$$\begin{aligned} \tilde{\Delta}_1^i &= \inf_x \quad G(x) - F(x) \\ \tilde{\Delta}_1^s &= \sup_x \quad G(x) - F(x) \cdot \end{aligned} \quad (6)$$

If both the inf and sup in equation (6) are positive then f dominates g. Alternatively, if the inf and sup in equation (6) are negative, g dominates f. If the inf and sup have different signs then there is no dominance in the first degree. All distributions that are not dominated comprise the set of first degree efficient alternatives.

The set of second-degree efficient alternatives can be similarly derived from the first-degree efficient set. Specifically, a sequence of binary comparisons:

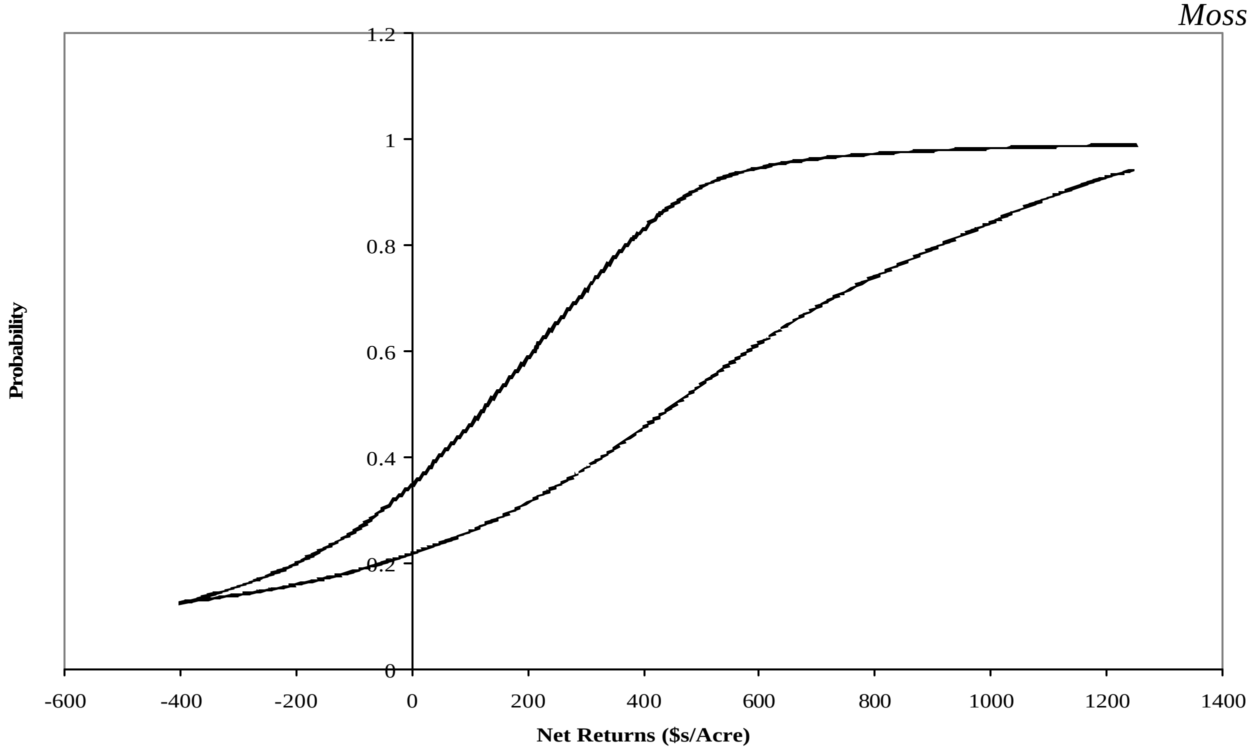

Figure 3. Cumulative Density Functions for Net Returns per Acre for Cotton and Peanuts Production in Jefferson County

$$\tilde{\Delta}_2^i = \inf_x \int_a^x \left[G(z) - F(z)\right] dz$$
$$\tilde{\Delta}_2^s = \sup_x \int_a^z \left[G(z) - F(z)\right] dz \quad . \; (7)$$

Again, if both the inf and sup have the same sign, then one distribution dominates the other in the second degree while a mixed sign implies a non-dominance relationship. In addition, the second-degree stochastic dominance criteria can be extended to focus on certain ranges of risk aversion using the results of Meyer.

3. Empirical Implementation of Decision Making Under Risk

The forgoing explanation of risk efficiency criteria relies on secondary data for collected for Jefferson County in Florida. Yields were taken to be county average yields while the cash price in the month of harvest was used as the output price. In order to develop a model of risk for coffee producers in Vera Cruz, more detail is required. Specifically, data for alternative methods of production and price mechanisms must be developed. Other studies have relied on various biological and economic simulators to develop the probability distributions for net return. Specifically, Riche and Boggess used a plant growth simulator to develop the yield distribution of soybeans under alternative irrigation regimes. Others have used economic models such as the USDA's SWAPSIM to generate price distributions.

At the most basic level, we are interested in developing a distribution for net revenue per acre. Net revenue per acre can be expressed as:

$$x = p \quad y - C(y) \, (8)$$

where p is the output price, y is the level of yield, and $C(y)$ is the cost of production. A common simplification is to model the cost of production as some fixed cost associated with an intended yield:

$$x = p \quad y\left(y^e\right) - C(y^e) \, (9)$$

where the producer applies inputs to obtain a target yield, y^e. Under this scenario, the distribution of yield is a function of this target level of yield, $y(y^e)$. The distribution of prices becomes a function of the marketing instrument used such as hedging, options, seasonal pooling, etc. The distribu-

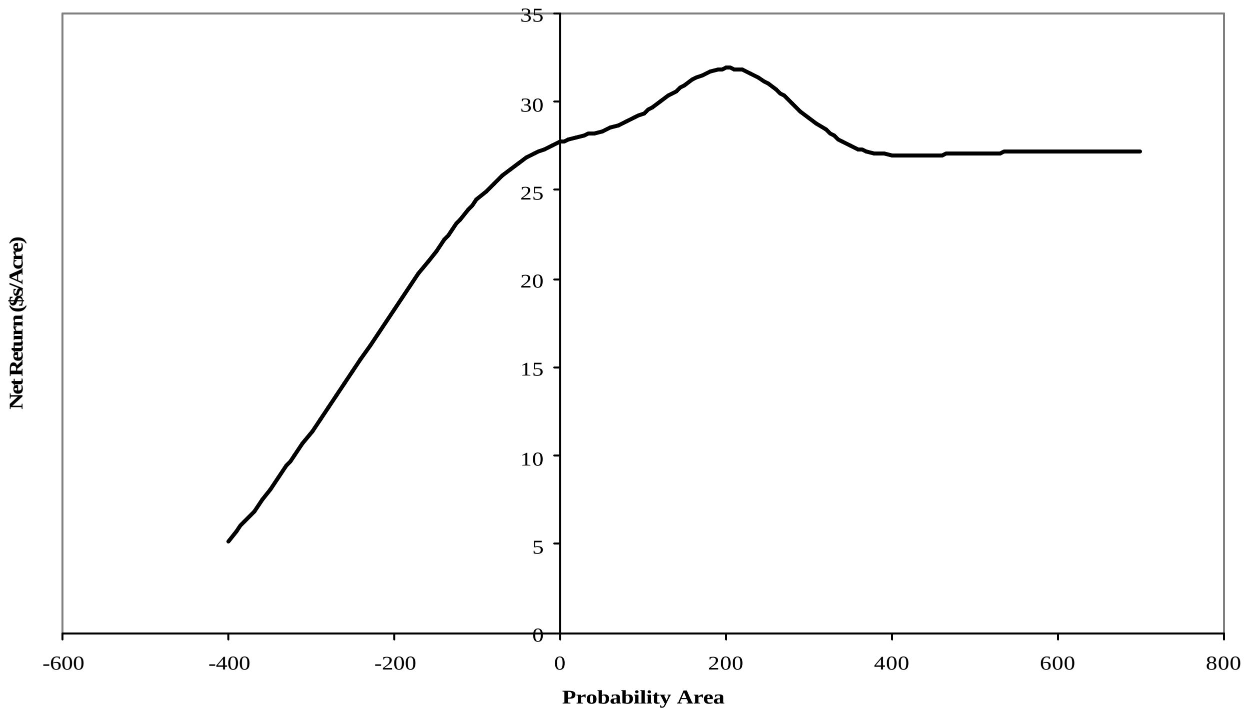

Figure 4. Differences in Area under Cumulative Distribution Functions

tion of yields is then dependent on production decisions such as fertilizer, pesticide, etc.

Secondary data for coffee production in Mexico is rather sparse. Table 2 presents coffee yield in thousand 60-kg bags by district. Table 3 presents the implied yield in 60-kg bags per hectare. These estimates were computed by dividing the total production in each state by the number of hectares in coffee in each state. Table 4 presents the expected yield per hectare, standard deviation of yield and coefficient of variation. In order to examine the relative variability of coffee production, table 5 presents the same figures for each crop in Jefferson County. This comparison indicates that the yield variability of coffee production in Chiapas, Vera Cruz, Oaxaca, and Guerrero are roughly comparable with the yield variability in Jefferson County. However, the relative variability in the other districts is far higher.

Turning to prices, table 6 presents the New York price for Columbian and other robusto coffees. These results indicate that other robusto coffees receive 67 percent of the price of Columbian robusto prices on average. The results in table 7 clearly indicate that coffee prices tend to be much more volatile than agricultural output prices in Jefferson County. This reduction in volatility could be attributed to two factors. Agricultural programs in the United States over the past half-century have stabilized commodity prices. This is especially true for corn, cotton and peanuts. Second, the significance of international trade in coffee relative to the commodities produced in Jefferson County may expose this market to relatively greater volatility.

While improvements in both yield and price data are necessary, these results suggest increased attention to the modeling of coffee prices. Specifically, additional information is necessary on the structure and performance of the Mexican coffee industry. The first studies should focus on competitiveness of coffee markets at the farm and intermediate levels. If the market is found to be competitive, further research can ascertain the effectiveness of various marketing tools in reducing the relative risk of coffee production in Mexico. If the market is found to be non-competitive, then research should focus on the relative risk bearing in oligopolistic markets.

Table 2. Coffee Production in Mexico by Region

	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
	THOUSANDS BAGS OF 60 KG.									
CHIAPAS	1686.80	1630.70	1842.22	1864.30	1783.93	1190.36	1304.39	1449.08	1742.60	1573.39
VERACRUZ	1610.00	1270.00	1329.78	1402.38	869.68	1211.48	1053.31	1571.70	1173.73	1392.38
OAXACA	613.00	748.50	780.46	965.23	695.27	711.82	663.53	764.34	736.41	490.22
PUEBLA	843.40	940.04	266.26	576.30	571.37	590.01	617.31	905.69	809.93	820.25
GUERRERO	170.58	198.18	224.32	201.87	193.10	241.36	167.13	223.87	231.02	202.75
HIDALGO	230.10	161.30	1.15	49.91	89.47	67.08	149.63	170.98	190.21	154.85
S.L.P.	145.70	76.78	0.84	10.97	60.26	44.51	75.20	81.00	74.91	46.27
NAYARIT	107.40	98.74	114.46	68.61	132.94	42.17	99.23	100.34	109.53	90.87
JALISCO	5.40	8.61	6.82	9.59	11.35	7.61	6.64	8.47	9.38	7.67
TABASCO	20.88	9.43	14.67	4.05	6.57	2.48	7.18	7.28	7.22	6.59
COLIMA	5.20	6.90	5.52	5.52	6.74	6.36	14.38	15.52	13.59	14.05
QUERETARO	2.30	1.15	0.00	0.77	1.15	1.00	1.74	1.75	1.37	1.63
TOTAL	5,440.76	5,150.33	4,586.50	5,159.50	4,421.83	4,116.24	4,159.67	5,300.02	5,099.90	4,800.90

Table 3. Coffee Production in 60 Kg Bags per Hectare

	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
CHIAPAS	7.390	7.144	8.071	8.168	7.816	5.215	5.715	6.349	7.634	6.893
VERACRUZ	10.560	8.330	8.722	9.199	5.704	7.946	6.909	10.309	7.699	9.133
OAXACA	3.528	4.308	4.491	5.555	4.001	4.096	3.819	4.399	4.238	2.821
PUEBLA	13.462	15.005	4.250	9.199	9.120	9.418	9.853	14.457	12.928	13.093
GUERRERO	3.360	3.903	4.418	3.976	3.803	4.754	3.292	4.409	4.550	3.993
HIDALGO	5.427	3.804	0.027	1.177	2.110	1.582	3.529	4.032	4.486	3.652
S.L.P.	4.531	4.166	4.829	2.895	5.609	1.779	4.187	4.233	4.621	3.834
NAYARIT	5.734	5.271	6.111	3.663	7.097	2.251	5.298	5.357	5.848	4.851
JALISCO	1.765	2.814	2.229	3.134	3.709	2.487	2.170	2.768	3.065	2.507
TABASCO	7.522	3.397	5.285	1.459	2.367	0.893	2.586	2.622	2.601	2.374
COLIMA	2.326	3.086	2.469	2.469	3.014	2.844	6.431	6.941	6.078	6.284
QUERETARO	6.479	3.239	0.000	2.169	3.239	2.817	4.901	4.930	3.859	4.592

Table 4. Yield Variability for Coffee Production

	Average Yield per Hectare	Standard Deviation	Coefficient of Variation
CHIAPAS	7.039	1.001	0.142
VERACRUZ	8.451	1.482	0.175
OAXACA	4.126	0.704	0.171
PUEBLA	11.078	3.304	0.298
GUERRERO	4.046	0.489	0.121
HIDALGO	2.983	1.682	0.564
S.L.P.	4.068	1.064	0.262
NAYARIT	5.148	1.347	0.262
JALISCO	2.665	0.558	0.210
TABASCO	3.111	1.937	0.623
COLIMA	4.194	1.954	0.466
QUERETARO	3.623	1.785	0.493

Table 5. Yield Variability for Jefferson County Crops

	Average Yield	Standard Deviation	Coefficient of Variation
Corn (Bu./Acre)	70.062	12.835	0.183
Soybeans (Bu./Acre)	25.960	4.934	0.190
Cotton (lbs./Acre)	654.800	114.627	0.175
Peanuts (lbs./Acre)	2606.000	313.589	0.120

Table 6. Coffee Price (cents/pound)

Year	Columbian Robusto	Other Robusto	Relative Price
1989-90	77.59	51.30	0.661
1990-91	79.39	52.46	0.661
1991-92	58.05	43.22	0.745
1992-93	66.34	48.25	0.727
1993-94	80.14	62.25	0.777
1994-95	161.07	135.22	0.840
1995-96	144.05	98.99	0.687
1996-97	160.21	76.65	0.478
1997-98	177.78	85.79	0.483

Following the discussion of the competitive market, alternatives include cash marketing, hedging, use of options, or the creation of pools. To this point, we have assumed that farmers market their output in a cash market and receive the prevailing market price. In order to develop a model of hedging and options, we model the price received by farmers as the sum of a market price and the gain on the marketing instrument:

$$\begin{aligned} p_h &= p_c + \left(p_f^0 - p_f^1\right) \\ p_o &= p_c + \left(p_p^0 - p_p^1\right) \end{aligned} \quad (10)$$

where p_h is the price received for a hedge, p_c is the price received in the cash market, p_f^1 is the price paid for the futures contract at the date the hedge is repurchased, p_f^0 is the price received for the futures contract at the date the hedge is set, p_o is the price received using options, p_p^1 is the price of the put option at the date the put option is repurchased, and p_p^0 is the price of the put option at the date the hedge is made. Rewriting this expression slightly, we have

$$\begin{aligned} p_h &= p_c + g_f \\ p_o &= p_c + g_p \end{aligned} \quad (11)$$

where g_f is the gain on the futures instrument and g_p is the gain on the put option. Computing the variance of each strategy in equation (11), we have

$$\begin{aligned} s_h^2 &= s_c^2 + s_f^2 + 2s_{cf} \\ s_o^2 &= s_c^2 + s_p^2 + 2s_{cp} \end{aligned} \quad (12)$$

where s_h^2 is the variance of the hedging strategy, s_c^2 is the variance of the cash price, s_f^2 is the variance of the futures instrument, s_{cf} is the covariance between cash and futures prices, s_o^2 is the variance of the option pricing strategy, s_p^2 is the variance of the put price, and s_{cp} is the covariance between cash and put prices. Under traditional assumptions, a covariance term that implies less than perfect correlation yields risk gains in the use of either instrument.

Marketing pools can be seen as an extension of the diversification framework over time. Specifically, assume that farmers produce their output in the first quarter of every year. One question of orderly marketing is then how to spread marketing out over the remainder of the year. Define the average price received during the year as

$$\hat{p} = a_1 p_1 + a_2 p_2 + a_3 p_3 + \left(1 - a_1 - a_2 - a_3\right) p_4 \quad (13)$$

where is the average annual price, is the share of crop marketed in period i, andis the prevailing market price in period i. Augmenting equation (13) for storage cost

$$\begin{aligned} \tilde{p} = {} & a_1 p_1 + a_2 e^{-\frac{1}{4}r} p_2 + a_3 e^{-\frac{1}{2}r} p_3 \\ & + \left(1 - a_1 - a_2 - a_3\right) e^{-\frac{3}{4}r} p_4 \end{aligned} \quad (14)$$

where r is the interest rate (implicitly we are ignoring other storage cost at this point). The variance of this market pool then becomes

$$\begin{aligned} s_{\tilde{p}}^2 = {} & a_1^2 s_1^2 + a_2^2 e^{-\frac{1}{2}r} s_2^2 + a_3^2 e^{-r} s_3^2 + \\ & \left(1 - a_1 - a_2 - a_3\right)^2 e^{-\frac{3}{2}r} s_4^2 + \\ & 2a_1 a_2 e^{-\frac{1}{4}r} s_{12} + 2a_1 a_3 e^{-\frac{1}{2}r} s_{13} + \\ & 2a_1 \left(1 - a_1 - a_2 - a_3\right) e^{-\frac{3}{4}r} s_{14} + \\ & 2a_2 a_3 e^{-\frac{3}{4}r} s_{23} + \\ & 2a_2 \left(1 - a_1 - a_2 - a_3\right) e^{-r} s_{24} + \\ & 2a_3 \left(1 - a_1 - a_2 - a_3\right) e^{-\frac{5}{4}r} s_{34} \end{aligned} \quad (15)$$

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[1] In fact, farmers may choose the optimal portfolio of marketing in each quarter. Taking the expectation of price for the pool yields

$$\begin{aligned} E\left[\tilde{p}\right] = {} & a_1 E\left[p_1\right] + a_2 e^{-\frac{1}{4}r} E\left[p_2\right] + \\ & a_3 e^{-\frac{1}{2}r} E\left[p_3\right] + a_4 e^{-\frac{3}{4}r} E\left[p_4\right] \end{aligned}$$

where *E[.]* is the expectation operator. The optimal quarterly sales can then be derived from

$$\begin{aligned} \min_{a_1, a_2, a_3} \quad & s_{\tilde{p}}^2 \\ s.t. \quad & E\left[\tilde{p}\right] \geq p_T \end{aligned}$$

where p_T is some target price.

where s_i^2 denotes the variance of price in a quarter and s_{ij} is the covariance between prices in quarter i and j. Typically farmers weigh the expected and variance gains to holding a portion of the crop for orderly marketing throughout the period.[1] However, credit constraints typically lead to small farmers marketing most of their product in the same period as the harvest.

To investigate the risk reduction offered by each of these marketing instruments, data on the price received by coffee producers throughout the year, futures price, option prices and export prices will be required. In addition to the straightforward analysis developed above, additional work on the effects of currency volatility and the potential effects of cross hedging in currency markets should be incorporated. It is possible that the greatest volatility in prices received by Mexican producers may result from currency fluctuations. In addition, there is a cross-hedging nature in coffee production. Specifically, producers want to hedge a certain variety of green coffee in Mexico while the hedge instrument specifies another quality delivered in New York. This introduces additional risk in the guise of transportation, processing and quality difference risk. For example, bad weather in Mexico may cause quality to be low. Thus, even if a hedge protects the producer from price variation for high quality coffee, it is not effective in protecting from price variation that results from quality discounts. In fact, a widespread crop shortfall may cause the quality discount to widen as the market bids up the price for higher quality coffee.

4. Summary, Conclusions, and Implications

The design of instruments that can be used by coffee producers in Mexico to control risk implies several questions. The preliminary results indicate that the dominant form of risk is the result of price variations. Specifically, while the coefficient of variation for coffee yields in Chiapas, Vera Cruz, Oaxaca, and Guerrero are consistent with observed yield variations for agronomic crops in Jefferson County, Florida, the coefficient of variation for coffee prices is much higher than the variation observed in the United States. This difference in variation may be partially explained by the presence of commodity programs in the United States.

Given the significance of price volatility in coffee production, future research into the design of instruments to control risk at the farm level should follow two tracks. The first track should examine the possibility of oligopolistic power in the coffee market. The results of Karp and Perloff suggest that some market power may exist. The existence of market power may have implications for the creation of an instrument to control risk at the farm level. The second track involves the analysis of alternative instruments or strategies such as the use of hedging, options, and pools. Analysis of the effectiveness of these instruments is dependent on the collection of farm and market level price data.

While the data suggest that the greatest gains could be expected by the design of instruments to control price risk, it needs to be pointed out that such risk reduction will imply a cost in reduced expected income. If the strategy involves futures market transactions such as the purchase and sale of futures or options, transaction cost will reduce the expected price. Similarly diversification over time in a pool implies storage and interest cost.

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