A MOTAD Approach to Risk Management Strategies for Vegetable Producers in Malaysia

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ABSTRACT

Most farm decisions are made under conditions of risk and uncertainty. In the last two decades, researchers in the agricultural economics discipline have increased their research efforts in finding convenient methods of incorporating risk directly in farm decision making models. MOTAD (Minimization of Total Absolute Deviation) developed by Hazell is an important result of these efforts and it has become a common method of incorporating risk in farm analysis. In this paper the MOTAD model is discussed and an empirical example is provided to show how the model can be used by managers to improve farm plans.

INTRODUCTION

The agricultural sector has remained the single largest and most important sector of the Malaysian economy. However, due to structural changes as a result of economic development the share of agricultural sector in terms of the total output has somewhat declined in recent years. In view of this decline in the agricultural sector, the National Agricultural Policy (NAP) was formulated in 1984 to ensure a balanced and sustained rate of growth in agricultural sector vis-a-vis the other sectors of the economy. It is clearly stated that, "the objective of the NAP is to maximize income from agriculture through efficient utilization of the country's resources and...". Income maximization here refers to both farm income and national income, incorporating the distributive as well as the growth aspects of economic development which would be attained through the efficient utilization of resources.

This study attempts to look at the process of maximizing income at the micro level, i.e. at the farm level. Specifically this paper will explore the response of the vegetable farmers to risk and uncertainty in their decision making for determining optimal income from a set of farm enterprises.

This study is motivated by several reasons. First, the conventional linear programming (LP) model which is widely recognised as a method for determining a profit maximization combination of farm enterprises with linear fixed farm constraints ignores risk and uncertainty. Second, as indicated by Hazell (1971), the LP solution is unrealistic and unacceptable to a farm operator on the basis of past experience. Previous studies on farm plans and decisions for Malaysian farmers were based on LP results. For example, Lai (1971) and Chiew (1976) applied the LP model to farm planning for vegetable farmers in Malaysia. A set of feasible farm plans that maximize income was generated from these studies. Nik Hashim (1978) used LP to study rice and tobacco farmers in Kelantan, while Nyanen (1981) used LP to look at the utilisation of unused paddy land; he came up
with different alternative farm plans for the area to maximize income. However, in all these studies, risk and uncertainty were ignored in the analysis. Thus this study is an attempt to take into account the risk and uncertainty in farm planning for Malaysian vegetable farmers in Alor Gajah, Melaka.

**Risk and Uncertainty in a Programming Model**

Response by decision makers to changes in risk has long been recognized as an important economic phenomenon. The study of decision makers' behaviour towards risk started to gain popularity as early as 1948 with the work of Friedman and Savage (1948) and was followed later by the work of Markowitz (1952) and Tobin (1958). Three sources of risk and uncertainty deserve attention in agriculture: risk associated with environmental and technological factors, risk associated with market factors and uncertainty with respect to policy changes.

Most of the research on risk and uncertainty done by the agricultural economics profession revolves around the first two sources - the environmental and the market factors. Studies by Mapp et. al (1979), Brink and McCarl (1978), Watts et. al (1984), Bogges et. al (1985), to name a few, all revolved around risk and uncertainty with regard to environmental and market forces. This paper is also concerned with these two sources of risk. However, its primary focus will be on uncertainties in activity costs, yields, and prices that affect the objective function of the conventional linear programming model. They may be summarised usefully as uncertainties in gross margins (gross returns net of variable costs). For this purpose several methods are available to consider gross margin uncertainties in farm planning. In this paper the MOTAD model introduced by Hazell (1971) is used to address optimal mixed crops under risk and uncertainty for Malaysian vegetable producers.

**MATERIALS AND METHODS**

**The MOTAD Model Specification**

Mean-Variance (E-V) analysis and MOTAD (Minimization of Total Absolute Deviation) have become common methods of incorporating risk into decision analysis. The approach developed by Hazell is most relevant when the variance of farm income is estimated using time series (or cross-sectional) sample data. It uses the mean absolute deviation (MAD) in place of variance as a measure of risk. The model is a two attribute model - risk and return. Return is measured as the sum of expected returns (E) of activities multiplied by their individual activity level and risk is measured as the expected sum of the total absolute deviation (A). The MOTAD formulation used in this study as proposed by Hazell is as follows

\[
\text{Minimize } W = \sum_{t=1}^{s} X_t Z_t \quad \cdots(1)
\]

such that

\[
\sum_{j=1}^{n} (c_{ij} - \bar{c}_j) X_j + Z_j \geq o_t \quad \cdots(2)
\]

and

\[
\sum_{j=1}^{n} (a_{ij} X_j) \leq b_i \quad \text{for all } i = 1, \ldots, m \quad \cdots(4)
\]

\[
X_j, Z_j \geq 0, \quad \text{for all } j \text{.} \quad \cdots(5)
\]

where

- \(X_j\) = the level of the jth activity
- \(C_j\) = the gross margin of the jth activity
- \(\bar{C}_j\) = the sample mean of gross margin for jth activity
- \(a_{ij}\) = the technical requirement of the jth activity for the ith resources or constraints
- \(b_i\) = the ith constraint level
- \(f_j\) = the expected gross margin of the jth activity
- \(\bar{x}\) = a scalar
- \(Z_j\) = the absolute value of negative total gross margin deviation around the expected return based on sample mean gross margin \(s\)
- \(s\) = mean absolute income deviation sample size of gross margins

The objective function in this model is to minimize the total absolute deviation. Equation (1) defines the absolute size of negative deviation in income from its mean. Equation (4) corresponds to the standard linear programming problem of maximizing expected gross margins. Because the model is linear in the objective function and constraints, the model can be solved by conventional linear programming code. Thus by parametrically varying \(X(X = 0 \text{ to unbounded})\)
over its feasible range, a sequence of solutions that minimizes MAD (Mean Absolute Deviation) for various gross margins is obtained. Simultaneously a set of farm plans that are efficient for expected income and mean absolute deviation (E-A) will be generated. The variance of income is calculated by using the MAD estimator \( V = (F/T)W \). The value F is called Fishers' constant where \( F = \left(2TC/(T-1)\right)^{1/2} \). T is the number of observation in the sample, n is the mathematical constant and W is the sum of square of the absolute value of income deviation. The MOTAD model may lack theoretical support, but it provides an efficient set of farm plans that is very similar to the solution obtained by quadratic programming. Earlier studies have shown that the E-V pairs for both models are almost identical although some discrepancies in crop hectarage occur. (Hazell 1971; Thomson and Hazell 1972).

**Farm Situation and Data Requirement**

This study examines a typical vegetable farm in Alor Gajah, Melaka. The typical farm in this region has three to four hectares of land. The production activities considered were restricted to vegetable crops: Long Beans (X1), Chilli (X2), Cabbage (X3), Cucumber (X4), French Bean (X5), Bitter Gourd (X6), Kai Lan (X7) and Sawi (X8).

The model farm could produce a mix of crops and the primary resource constraints are field time by season, land and labour. The crop year is based on 6-month time period (i.e. from January to June). Since most of the vegetable crops considered require a shorter life cycle, the possible rotation will be based on the time required from planting till harvesting. Table 1 summarises the time frame (season) for each crop considered in the analysis. The typical farm was endowed with 1000 h of family labour. Hiring of farm labour was restricted to a total of 900 h for the months of March, April and May at $1.50 per h.

The production coefficients and products and input prices information or data required for different crops selected, were obtained from a farm survey and *Business Proposal For A Commercial Mixed Vegetable Farm in Peninsular Malaysia* published by MARDI. The generalised initial tableau for the MOTAD model is presented in Table 2.

**RESULTS AND DISCUSSION**

Based only on average returns above cost per hectare and with no consideration for variance, the production activities ranking from high to low are as follows

1. Chilli (X2)
2. Cabbage (X3)
3. Kai-Lan (X7)
4. Bitter Gourd (X6)
5. Long Bean (X1)
6. French Bean (X5)
7. Sawi (X8)

The set of optimal farm plans for a typical vegetable farm in Alor Gajah, Melaka was obtained and the results are reported in Tables 3 and 4. Table 3 shows the combination of activities for a typical vegetable farm in Alor Gajah where only family labour is used. The results in Table 4 allow for hired labour in the formulation. The income standard deviation reported in the tables was computed using the MAD estimator defined in the earlier section.

In general, the results suggest that low levels of expected returns correspond to low levels of risk. A farmer with low risk aversion would select combination 1 where almost all the LP solution is of maximizing expected returns. The combination of 0.92 hectares of X21 (Chilli), 0.64 hectares of X54 (French Bean), 0.10 hectares of X71 (Kai-Lan), 1.14 hectares of X74 (Kai-Lan) and 2.19 hectares of X75 (Kai-Lan) yield an expected return of about $95 thousand but has the highest risk aversion.

Note that X21 indicates chilli crop planted in the month of January, similarly X75 indicates Kai-Lan crop planted in May etc. Thus, the second number of the crop code is the planting month. For example No. 1 indicates the month of January and No. 2 indicates the month of February.
### TABLE 2
Initial tableau for the MOTAD Model
(General Form)

<table>
<thead>
<tr>
<th>Resource Restrictions</th>
<th>(X_1)</th>
<th>(X_2)</th>
<th>(X_3)</th>
<th>(\ldots)</th>
<th>(X_m)</th>
<th>(Y_1)</th>
<th>(Y_2)</th>
<th>(Y_3)</th>
<th>(\ldots)</th>
<th>(Y_t)</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OBJECTIVE FUNCTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MINIMIZE</td>
</tr>
<tr>
<td>Resource 1 (a_{11})</td>
<td></td>
<td></td>
<td></td>
<td>(a_{12})</td>
<td></td>
<td>(a_{13})</td>
<td>(\ldots)</td>
<td>(a_{1n})</td>
<td></td>
<td></td>
<td>(b_1)</td>
</tr>
<tr>
<td>Resource 2 (a_{21})</td>
<td></td>
<td></td>
<td></td>
<td>(a_{22})</td>
<td></td>
<td>(a_{23})</td>
<td>(\ldots)</td>
<td>(a_{2n})</td>
<td></td>
<td></td>
<td>(b_2)</td>
</tr>
<tr>
<td>Resource 3 (a_{31})</td>
<td></td>
<td></td>
<td></td>
<td>(a_{32})</td>
<td></td>
<td>(a_{33})</td>
<td>(\ldots)</td>
<td>(a_{3n})</td>
<td></td>
<td></td>
<td>(b_3)</td>
</tr>
<tr>
<td>(\ldots)</td>
<td></td>
<td></td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td></td>
<td>(\ldots)</td>
</tr>
<tr>
<td>Resource (m) (a_{ml})</td>
<td></td>
<td></td>
<td></td>
<td>(a_{m2})</td>
<td></td>
<td>(a_{m3})</td>
<td>(\ldots)</td>
<td>(a_{mn})</td>
<td></td>
<td></td>
<td>(B_m)</td>
</tr>
<tr>
<td>1</td>
<td>(D_{11})</td>
<td>(D_{12})</td>
<td>(D_{13})</td>
<td>(\ldots)</td>
<td>(D_{1n})</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>(D_{21})</td>
<td>(D_{22})</td>
<td>(D_{23})</td>
<td>(\ldots)</td>
<td>(D_{2n})</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>(D_{31})</td>
<td>(D_{32})</td>
<td>(D_{33})</td>
<td>(\ldots)</td>
<td>(D_{3n})</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\ldots)</td>
<td></td>
<td></td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td>(\ldots)</td>
<td></td>
<td></td>
<td>(\ldots)</td>
</tr>
<tr>
<td>(t)</td>
<td>(D_{t1})</td>
<td>(D_{t2})</td>
<td>(D_{t3})</td>
<td>(\ldots)</td>
<td>(D_{tn})</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>(C_1)</td>
<td>(C_2)</td>
<td>(C_3)</td>
<td>(\ldots)</td>
<td>(C_n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where
- \(a\) is an \(m \times n\) matrix of technical coefficients
- \(B\) is an \(m \times n\) vector of resources and other restraints
- \(X\) is an \(n \times l\) vector of activities
- \(Y\) is the \(n \times l\) absolute value of the negative total gross margin deviation
- \(D\) is the \(m \times n\) matrix of \(Y\)
- \(C\) is an \(n \times l\) vector of net gross margins
### TABLE 3
MOTAD solutions for a farm with family labour only.

<table>
<thead>
<tr>
<th>EXPECTED INCOME</th>
<th>MODEL I</th>
<th>MODEL II</th>
<th>OBJECTIVE FUNCTION</th>
<th>ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>95065.41</td>
<td>95865.41</td>
<td>479934.13</td>
<td>X21 1.92</td>
</tr>
<tr>
<td>2.</td>
<td>90065.41</td>
<td>89018.15</td>
<td>45097.53</td>
<td>X51 0.642295</td>
</tr>
<tr>
<td>3.</td>
<td>85065.41</td>
<td>8485.99</td>
<td>42429.53</td>
<td>X53 0.099482</td>
</tr>
<tr>
<td>4.</td>
<td>80065.41</td>
<td>7952.75</td>
<td>39762.34</td>
<td>X71 1.088932</td>
</tr>
<tr>
<td>5.</td>
<td>75065.41</td>
<td>7418.95</td>
<td>37094.74</td>
<td>X73 2.186081</td>
</tr>
<tr>
<td>6.</td>
<td>70065.41</td>
<td>6885.43</td>
<td>34427.14</td>
<td>X74 2.530273</td>
</tr>
<tr>
<td>7.</td>
<td>65065.41</td>
<td>6351.91</td>
<td>31759.54</td>
<td>X75 2.16756</td>
</tr>
<tr>
<td>8.</td>
<td>60065.41</td>
<td>5818.39</td>
<td>29091.95</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>55065.41</td>
<td>5332.23</td>
<td>26661.13</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>50065.41</td>
<td>1848.05</td>
<td>1.766106</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>45065.41</td>
<td>4363.88</td>
<td>1.605741</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>40065.41</td>
<td>3879.71</td>
<td>1.445377</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>35065.41</td>
<td>3395.54</td>
<td>1.285013</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>30065.41</td>
<td>2911.37</td>
<td>1.124648</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>25065.41</td>
<td>2427.19</td>
<td>0.964284</td>
<td></td>
</tr>
</tbody>
</table>

where standard deviation is computed using the formula $SD = \sqrt{\frac{\sum (X - \bar{X})^2}{n}}$ X MAD. In model II the fisher transformation, where $SD = \sqrt{\frac{2\pi}{S(S-1)}} x TDN$. Here $S$ denotes the number of observations in the sample, MAD is the total estimated mean absolute deviation and TDN is the total absolute deviation.
where standard deviation is computed using the formula \( SD = \sqrt{\frac{2n}{S(S-1)} \times TDN} \). Here \( S \) denotes the number of observations in the sample, MAD is the total estimated mean absolute deviation and TDN is the total absolute deviation.
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coefficient. At the other extreme, a farmer with high risk aversion would select combination 15 where most of the land is idle. The solution for this combination yields an expected return of $55 thousand.

Solutions with small standard deviation of returns include crops like Chilli and Kai-Lan. As the standard deviation of returns is increased, the area planted with X5 (French Bean) and Kai-Lan (X7) increased while the area under Chilli became less. From the results, we can conclude that French Bean (X5) and Kai-Lan (X7) are among the high risk crops. Note that the area planted with Kai-Lan increased from 0 hectares to 2.1 hectares as the risk coefficient increased for the case of the family farm.

The general results hold for the farms employing hired labour but the hectareage as well as the expected returns are higher in the case of hired labour. For example, if the standard deviation is about 9800 only 1.92 hectares of Chilli and 1.70 hectares of Kai-Lan are planted for the family farm but with additional labour from hired labour, the optimal farm plan consists of 2 hectares of Chilli and about 2.32 hectares of Kai-Lan for the 6-month planting period.²

The efficient mean-variance (E-V) frontiers for the MOTAD model are provided in Figure 1. The frontier for the hired labour case is above the frontier for the family farm (NHL) for all levels of expected returns. These results provide the evidence that vegetable farmers could reduce their risk by hiring labour to enhance (or supplement) family farm labour.

CONCLUSION

Programming models intended to provide an insight on planning may cause planners to obtain farm plans which are unacceptable to the farm operator. It would be unwise for the planners to advise producers to plant only the most risky crops based on the fact that it will yield the highest returns.

Risk programming techniques which have been developed by Hazell called the MOTAD Approach were used to investigate vegetable farm planning in Alor Gajah, Melaka. The model is attractive because it enables us to do post-optimal analysis and under certain assumptions produce identical results to the quadratic programming model. The findings from this study closely reflect the "real" farm situation in the area compared to the solution provided by the LP model. Further, it was found that vegetable farmers could lower their risk by hiring farm labour rather than depending on family labour for all the farm operations.

REFERENCES


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*The mean-deviation matrix for a 18-year period does not yield results significantly different from those constructed for a 10-year period.


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