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Trade-Offs between Risks and Returns of Multiple Vegetable Cropping Systems

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ABSTRAK

Pengeluaran penanaman pertanian adalah satu perniagaan yang berisiko. Petani menghadapi variasi di dalam harga, hasil pengeluaran dan sumber terkonstren yang mewujudkan satu pendapatan yang tidak stabil. Objektif kajian ini adalah untuk melihat akan tukar-ganti di antara pulangan (E) dan risiko (V) (yang diukur oleh varians pulangan dijangka) di dalam program mempelbagaikan penanaman sayur-sayuran. Disamping itu, kajian ini akan memberi satu perancangan perladangan yang mempunyai risiko yang minimum kepada petani untuk menagihkan sumber-sumber perladangan untuk penanaman sayur-sayuran yang lebih cekap dibawah keadaan risiko dan ketidakpastian. Sempadan E-V juga dikesan untuk menilai tukar-ganti di antara risiko dan pulangan jangkaan untuk setiap campuran penanaman sayur-sayuran. Kajian mendapati bahawa petani yang mempunyai keputusan gelagat pengelak risiko iaitu yang berada dibahagian bawah sempadan E-V sepatutnya menanam lebih banyak sayur bendi, bayam dan timun. Manakala petani yang mempunyai gelagat berkecuali risiko, iaitu yang berada dibahagian atas sempadan E-V sepatutnya menanam sayur-sayuran yang mempunyai risiko yang tinggi seperti peria dan kailan.

ABSTRACT

Production of crops as a business venture is considered risky. A farmer faces variations in prices, yield and resource constraints that make income unstable. This study looks at the trade-off between farm returns (E) and risk (V) (as measured by variance of expected income) in a vegetable crop diversification programme. The study demonstrates how minimum risk farm plans can be estimated to allocate available land to match the vegetable crop combinations efficiently in situations of risk and uncertainty. The E-V frontier is traced to evaluate the trade-offs between risks and returns of each combination of the vegetable crops. The results indicate that farmers with high risk aversion i.e. at the lower E-V frontier should plant more "ladies fingers" spinach and cucumber, while farmers who are risk neutral i.e. at the higher E-V frontier should plant more high risk crops such as bitter gourd and "kailan".

INTRODUCTION

In agricultural production factors can be classified as controlled and uncontrolled. Uncontrolled factors cause uncertainties in output and prices. Climate, for example, may prevent actual production reaching planned levels. And it may also affect of the price of the agricultural product. Changes in prices may also stem from changes in the world market due to changes in the level of demand and supply of agricultural products in various countries. This uncertainty of price also causes the income and revenue of the farmers to be unstable.

One way to reduce the risk is by diversifying the farming system. According to the comparative advantage theory, specialization in monoculture crop production can lead to maximum profit; however, the level of profit is uncertain by price and yield fluctuations. Diversification can reduce risks but this can normally be attained only at the expense of income, that is, the trade-off between returns and risks.

An important question faced by growers is, "what combination of crops can reduce risks in income?". Apart from the problem of risks in prices and yields, the Malaysian vegetable industry is characterised by uneconomical land size and limited marketing outlets. Thus, in view of the climatic and physical conditions, the suitability of vegetable crops might be determined without much difficulty. However, if economic conditions are taken into account, the decision becomes more difficult. The choice of vegetable crop combinations may increase or reduce risks.

The objective of this study is to look at the trade-off between the return and risk in vegetable crop combinations experienced in Bukit Teh, Seberang Perai. The study will suggest a minimum risk farm plan in which a farmer allocates the available land for a vegetable crop combination which efficiently pre-empts possible risks. This paper focuses primarily on uncertainties in price, yield, and cost of vegetable crop production that affect the objective function of the conventional linear programming model. The study also estimates the production efficiency frontiers for the farmer. This frontier is then used to evaluate the trade-offs between risks and returns for each combination of vegetable crops.

THEORETICAL FRAMEWORK

Variations in prices, yields, and resources make farmers' income unstable and in turn affect their utility. Generally, the farmers' utility varies according to their attitudes toward risk. The attitude toward risk can be classified into three groups (Somnuk, 1981): risk averse, risk neutral and risk prefer.

These three attitudes toward risk cause farmers to behave in typically risk-averse ways. Dillon and Scandizzo (1978) and Binswanger (1980) have demonstrated that farmers often prefer farm plans that provide a satisfactory level of security even if this means sacrificing their income on average. In farm planning under risk, Roumasset (1979) suggests that risk-aversion is one of the motives for diversification. However, the problem for the farmer is to rank farm plans and to select the one that best meets his/her goals.

There are many alternative decision theories by which farm plans can be ranked. The most established decision theory is the expected utility theory developed by Von Neumann and Morgenstern (Hazell and Norton 1986). This theory asserts a set of axioms on how an individual ought to order risky prospects. From this expected utility theory, one can derive the expected income-variance or E-V criteria (EV). Given a set of efficient farm plans the efficient E-V boundary can be derived and the acceptability of a plan will depend on the farmer's EV utility function (see Lindon *et al.* 1984 for a detailed discussion on the expected utility theory).

MATERIALS AND METHOD

Risk Models for Farm Planning under Expected Utility Theory

The MOTAD (minimization of total absolute deviation) model developed by Hazell (1971) has been widely used in incorporating risks into a decision analysis study. The approach is similar to E-V analysis except that the total absolute deviation of total gross margin (A) is minimized in preference to minimizing variance (V) for any total gross margin level. In this model framework, observations of mean absolute deviation (MAD) are used as a measure of risk for each production alternative. By parametrically varying the level of net return from zero to a maximum value, an efficient set of farm plans that are efficient for expected income and MAD i.e. (E-A) will be generated. This set of plans is referred to as an E-A efficient frontier. The MOTAD derived frontier is estimated by minimizing MAD across the production alternatives for a particular level of expected returns.

The variance of the expected income is calculated by using the MAD estimator $V = (F/T^2)W$. The value of F is called Fishers' constant, where $F = [T\pi/2(T-1)]$. T is the number of observations in the sample, π is the mathematical constant and W is the absolute value expected income deviation (Hazell and Norton 1986).

One of the appealing aspects of the MOTAD technique is its ability to incorporate risk preferences in a linear programming (LP) algorithm. The linear programming formulation of this type is typically less expensive compared to non-linear optimization counterparts. The MOTAD procedure is applied in this study to generate risk efficient farm plans for vegetable producers in Bukit Teh, Seberang Perai, to enable them to achieve set objectives.

Specification of MOTAD Model for the Vegetable Crops

The objective of the vegetable crop model is to minimize risk for each level of gross margins subject to the resource constraint. That is,

$$\text{Min.} \sum_{h=1}^{s} Y_h \qquad [1]$$

Subject to

$$\sum_{j=1}^{n} (C_{hj} - G_j)\, X_j + Y_h \geqslant 0 \qquad [2]$$

(for all h; h = 1,.........s)

$$\text{and} \sum_{j=1}^{n} F_j X_j \geqslant t \qquad [3]$$

$$\sum_{j=1}^{n} A_{ij} X_j \leqslant B_i \qquad [4]$$

(for all i, i = 1,.........m)

$$X_j,\ Y_h \geqslant 0 \qquad [5]$$

(for all h,j)

Where, h = the sample period of gross margins

i = the number of constraints which include land, labour and capital.

j = the number of activities which compose several vegetable crops

Y_h = the absolute values of the negative total gross margin deviation from each crop (ringgit).

C_{hj} = the gross margin of each crop in the h^{th} period (ringgit).

G_j = the mean of gross margin of the j^{th} crop (ringgit).

X_j = the level of activity j which means the planted area of the j^{th} crop (hectares)

E_j = the expected gross margin of the j^{th} crop (ringgit) per hectare

A_{ij} = the coefficient representing the i^{th} resources requirement for the j^{th} crop.

B_i = the level of resource or constraint i.

t = a scalar, the expected gross margin (ringgit), which may be parameterized to generate points on the E-A frontier

Equation [1] states that the objective of the producer is to minimize the quantity of the negative deviation of gross income from their mean of growing the different vegetable crops during the sample period. Equation [4] indicates that this minimization is conditioned by three constraints, land, labour and capital which correspond to the standard linear programming problem of maximizing expected gross margins.

Farm Resources and Constraints

The modified MOTAD model was applied to obtain the efficiency allocation of resources in farm planning under risk and uncertainty in vegetable crop price, yield, and cost in the Bukit Teh situation.

TABLE 1
Length of crop cycle in terms of number of sequential periods

Vegetable (Code)	Length of Crop Cycle (Months)
"Ladies fingers" (X1) (*Hibiscus esculentus*)	8
Bitter gourd (X2) (*Momordica charan*)	4
Spinach (X3) (*Amaranthus gangeticus*)	1
"Kailan" (X4) (*Brassica alboglabra*)	1
Long beans (X5) (*Vigna sesquipedalis*)	3
Cucumber (X6) (*Cucumis sativus*)	4

Source: MARDI Farm Survey

This study emphasises the intensity of land use in multiple vegetable cropping. The suggested cropping system includes "ladies fingers" (X1), bitter gourd (X2), spinach (X3), "kailan" (X4), long beans (X5) and cucumber (X6). The period of a crop cycle in terms of a sequential period occupied for these vegetables is between one month to eight months (Table 1). The main resources that determine the production of vegetable cultivation are land, labour and capital.

A typical farm in Bukit Teh is modelled for small, medium and large farms. Lands allocated for these farms are 1.5, 2.0, and 2.5 hectares, respectively. It is assumed that the technology is the same irrespective of farm size.

The main source of labour required in the typical farm operation is family labour. The efforts contributed by the farmers are calculated on a man/day basis. It is assumed that total working days per month is 30 days. The number of labourers for small, medium and large farms are 2.0, 3.0, and 4 persons, respectively. Therefore, total working days available are 60, 90, and 120 per month for small, medium and large farms, respectively. The other source of labour is hired labour. Hired labour are paid a basic salary of RM10.00 per day and are assumed to work up to 30 days per month. The major types of work are categorized as land preparation, applying fertilizer, planting, maintenance and harvesting.

Capital is one of the important constraints in farm operations and it refers to the expenditure incurred on inputs such as seeds, herbicides, pesticides, fertilizers and other equipment. The maximum capital available for small, medium and large farms is assumed to be RM1000, RM2000, and RM3000, respectively. No capital borrowing was assumed in this study.

The MOTAD formulation requires a time series (yearly) gross margins for each crop activity to accommodate Equation 2. The yield data were obtained from a survey conducted by FAMA (Federal Agricultural Marketing Authority) on area planted and the yield. To obtain the gross income the yield is multiplied by the average price received by farmer for each year. The estimated cost of production is based on 1988 figures. Since the time series data for cost of production are not available, the cost of production is computed by using the agricultural production index, using the 1988 cost as a base. Thus, by deducting the cost of production from gross income, gross margins are obtained for the respective years. All calculations are based on per ha/season of cycle. One crop might have 2 or 3 seasons per year; thus the yield, and prices used are the average for the year.

Table 2 shows the gross margins of the activities and their variances and covariances over the past eight years. Activity X1 and X4 are found to be more profitable on average, but have highly variable gross margins as shown by the activity variances.

The estimation of the model is based on a monthly basis. Thus, the technical coefficient

TABLE 2

Activity gross margins and their variances and covariances

	Crop Activities					
	"Ladies Fingers" (X1)	Bitter Gourd (X2)	Spinach (X3)	"Kailan" (X4)	Long Bean (5)	Cucumber (X6)
	Gross Margin (RM/ha)					
1983	20910	7036	6659	16289	7261	8919
1984	21744	8405	6200	15863	8040	4338
1985	23573	9163	6962	16714	8883	2280
1986	14911	8577	2680	12065	5226	2963
1987	16443	10119	3429	9271	6490	5386
1988	17732	7544	5480	8435	6740	4921
1989	18458	10396	3866	13781	10262	5905
1990	17352	11511	4985	15270	9949	5038
Average	18890	9081	5033	13461	7857	5094
	Variances - Covariances					
	(X1)	(X2)	(X3)	(X4)	(X5)	(X6)
(X1)	7487686	-1086643	3624570	5813613	1870585	-485906
(X2)		1965085	-832063	215466	1349561	-694189
(X3)			2175029	2621894	775532	135098
(X4)				9061208	2702526	153795
(X5)					2702825	-87944
(X6)						3146995

for each planting month is also assumed to be the same. For example, a crop planted in February will have the same technical coefficients as a crop planted in January.

RESULTS AND DISCUSSION

The optimum solutions obtained from applying data to the MOTAD basic model are presented and discussed. The solutions are the set of the minimum-risk farm plan for the given gross margins and provide a range of gross margins-risk possibilities indicating the efficient risk-gross margins farm plan for vegetable production.

Minimum Risk Farm Plan for the Small Farm

The minimum risk farm plan solutions for the small farm are shown in Table 3. At each gross margin, the cropping patterns and their associated risks are given. In plan 1 with the lowest gross margins and risk level of about RM51799.82 and RM6354.01 respectively, bitter gourd (X2) becomes the largest vegetable crop planted area at 48.90% of the overall activities. "Ladies fingers" (X1), spinach (X3), "kailan" (X4) and cucumber (X6) have planted areas at 35.67%, 11.02%, 2.81%, and 1.80% of the overall activities, respectively. If a farmer wishes to earn 4000 ringgit more than the lowest expected gross margin suggested i.e., to achieve the gross margin of RM55799.82 (i.e. Plan 2), he/she should reduce the area planted with "ladies fingers" (X1), spinach (X3) and cucumber (X6)and increase the planted area with bitter gourd (X2) and kailan (X4). Plan 2 also potentially increases earnings to RM3133.67 with a marginal rate of risk ($\Delta R/\Delta GM$) of about RM0.778, which means that for a unit change of the gross margins, the risk of the farm plan will change by about RM0.778. On the other hand, a farmer desiring to achieve the gross margins more like those suggested in Plan 3 than in Plan 8, "ladies fingers" (X1) and spinach (X3) in the planted area should be decreased and replaced by bitter gourd (X3) and "kailan" (X4). Both bitter gourd (X3) and "kailan" (X4) are high value crops (per unit price is high). Thus, it is logical for a low risk aversion farmer to select farm Plan 8 where expected returns are maximized. The risk in accordance with these farm plans also increases. It is noted that the risk increases as the marginal risk ($\Delta R/\Delta GM$) is increased from Plan 1 to Plan 8. This indicates that there is a trade-off between risk and return in farm plan i.e., higher gross margins can be obtained in exchange for higher risks.

Minimum Risk Farm Plan for the Medium Farm

For the medium farm, the minimum risk farm plan solutions are presented in Table 4. Based on the assumption of efficiency utilization of land resource, the feasible gross margins range of RM51799.82-RM79799.82 are computed. In the lowest gross margins farm plan of RM51799.82, land is allocated for "ladies fingers" (X1), bitter gourd (X2), spinach (X3), and cucumber (X6) at 31.68%, 51.30%, 2.89%, and 14.11% of the overall activities, respectively. As in the case of small farms if a farmer wants to obtain more from the gross margins, he

TABLE 3
Minimum risk farm plan of small farm

Plan	Gross Margin (GM) (Ringgit) (t)	Risk (R) (Ringgit) (Variance)	ΔGM	ΔR	ΔR / ΔGM	Percentage of Planted Area					
						"Ladies fingers" (X1)	Bitter gourd (X2)	Spinach (X3)	"Kailan" (X4)	Long beans (X5)	Cucumber (X6)
1	51799.82	6354.01	–	–	–	35.36	48.90	11.02	2.81	0.00	1.80
2	55799.82	9467.68	4000	3113.67	0.778	26.93	61.51	6.75	4.80	0.00	0.00
3	59799.82	12625.29	4000	3157.61	0.789	22.74	65.85	3.64	7.75	0.00	0.00
4	63799.82	15830.34	4000	3205.5	8.801	18.31	70.73	0.56	10.77	0.00	0.00
5	67799.82	19374.06	4000	3543.72	0.885	7.27	79.00	0.15	13.56	0.00	0.00
6	71799.82	23008.69	4000	3634.63	0.908	0.00	83.89	0.00	16.05	0.00	0.00
7	75799.82	26737.04	4000	3728.35	0.932	0.00	81.88	0.00	18.11	0.00	0.00
8	79799.82	30526.23	4000	3789.19	0.947	3.18	76.77	0.00	20.04	0.00	0.00

TABLE 4
Minimum risk farm plan of medium farm

Plan	Gross Margin (GM) (Ringgit) (t)	Risk (R) (Ringgit (Variance)	ΔGM	ΔR	ΔR/ΔGM	Percentage of Planted Area "Ladies fingers" (X1)	Bitter gourd (X2)	Spinach (X3)	"Kailan" (X4)	Long beans (X5)	Cucumber (X6)
1	51799.82	1237.06	–	–	–	31.68	51.30	2.89	0.00	0.00	14.11
2	55799.82	3012.48	4000	1775.42	0.44	21.95	57.34	5.75	0.21	0.00	14.72
3	59799.82	5723.04	4000	2710.56	0.66	21.66	58.98	5.21	1.41	0.00	12.71
4	63799.82	8552.89	4000	2829.85	0.707	21.80	61.54	8.90	1.43	0.00	6.30
5	67799.82	11618.49	4000	3065.60	0.766	21.75	61.99	6.72	3.34	0.00	6.18
6	71799.82	14692.50	4000	30.74.01	0.768	19.49	64.83	5.49	5.09	0.00	5.07
7	75799.82	17769.95	4000	3077.45	0.769	19.56	66.66	5.46	6.09	0.00	2.20
8	79799.82	20949.00	4000	3179.05	0.794	17.72	69.30	5.00	7.96	0.00	0.00

should substitute "ladies fingers" (X1) and cucumber (X6) with bitter gourd (X2), spinach (X3) and kailan (X4) (Table 4). Likewise, the risk related to these farm plans also increases with an increasing rate as the marginal risk (ΔR/ΔGM) is increased from RM0.44 to RM0.794 in Plan 1 to Plan 8 respectively. This also implies that there is a trade-off between risk and return in farm plan solutions of the medium farm size. High value crops like bitter gourd (X2), spinach (X3) and "kailan" (X4) should be selected for the highest risk farm plan.

Minimum Risk Farm Plan for the Large Farm

Similarly the feasible gross margins range of RM51799.82-RM79799.82 are also computed for the large farm. Table 5 shows the trade-off between risk and expected income for different sets of plans. The results suggest that a low level of expected returns corresponds to a low level of risk. A farmer who has a high risk aversion would select farm Plan 1. "Ladies fingers" (X1) is the largest vegetable crop planted at 47.81% of the overall activities compared to 36.92% and 15.25% of bitter gourd (X2) and cucumber (X6), respectively. The risk of this plan is RM689.40. To attain more gross margins, a farmer should reduce "ladies fingers" (X1), cucumber (X6), and grow more bitter gourd (X2). This is so because the gross margins of bitter gourd (X2) are higher than those of "ladies fingers" (X2) and cucumber (X6). The risk of farm plans also increases with the gross

TABLE 5
Minimum risk farm plan of large farm

Plan	Gross Margin (GM) (Ringgit) (t)	Risk (R) (Ringgit (Variance)	ΔGM	ΔR	ΔR/ΔGM	Percentage of Planted Area "Ladies fingers" (X1)	Bitter gourd (X2)	Spinach (X3)	"Kailan" (X4)	Long beans (X5)	Cucumber (X6)
1	51799.82	689.40	–	–	–	47.81	36.92	0.00	0.00	0.00	15.25
2	55799.82	1576.62	4000	887.22	0.222	46.31	38.94	0.00	0.00	0.00	14.73
3	59799.82	2463.83	4000	887.21	0.221	40.83	46.20	0.00	0.00	0.00	12.99
4	63799.82	3880.71	4000	1416.88	0.354	36.48	46.02	2.45	0.00	0.00	15.03
5	67799.82	5420.26	4000	1539.55	0.384	25.35	55.09	4.79	0.00	0.00	14.75
6	71799.82	7369.72	4000	1949.46	0.478	17.35	60.17	4.83	0.90	0.00	16.74
7	75799.82	10.297.56	4000	2927.84	0.731	15.51	62.35	3.69	2.29	0.00	16.14
8	79799.82	13371.66	4000	3074.10	0.768	15.50	63.67	3.97	3.18	0.00	13.62

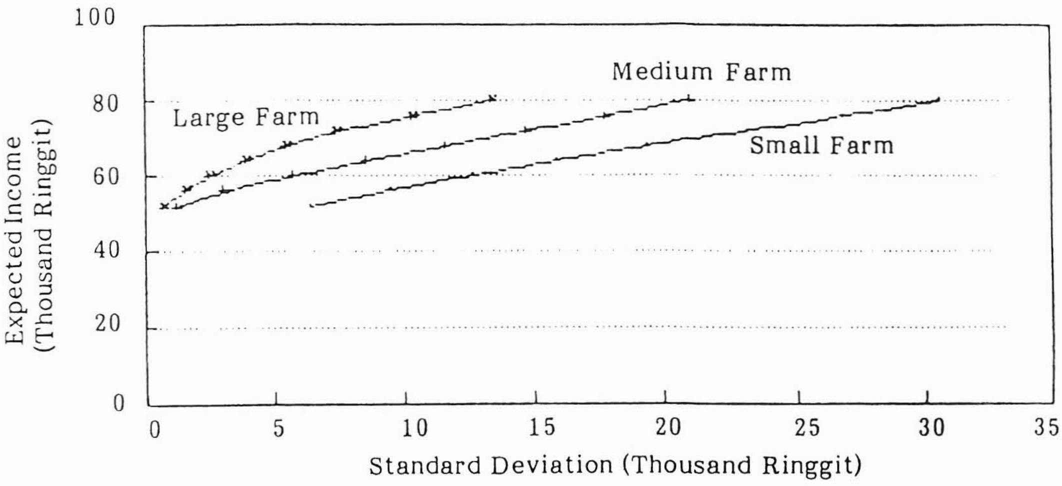

Fig. 1. E-V frontiers for small, medium and large farms

margin as we move from Plan 1 to Plan 8. This also reflects that there is a trade-off between return and risk in large farms as the marginal risk ($\Delta R/\Delta GM$) is increased.

Fig. 1 shows the E-V frontier for the small, medium and large farms. The frontier for the large farm is above the medium farm while the frontier of the medium farm is above the small farm for all levels of expected returns. The figure indicates that with the same amount of risk the expected return is higher for a large farm compared to that for medium and small farms. This could be due to the land constraint on the medium and small farms. This is also the case when a small farm tries to attain the highest expected income as is the case with the large farms. The risk also increases accordingly by about 3.5 times.

The results of this study suggest that, although land, capital and labour could be constraints to small and medium farms, it is possible for them to achieve a higher expected income with higher risk. From the results we can also conclude that bitter gourd (X2), "kailan" (X4) and spinach (X3) are among the high risk crops.

SUMMARY AND CONCLUSIONS

This study has derived the E-V frontiers for farmers in Bukit Teh and evaluated the trade-off between risks and expected incomes in vegetable production. This efficiency frontier is derived from the minimum-risk farm plans which integrate the efficient allocation of available resources with a combination of vegetable crops in a situation where prices, yields, and costs of vegetable production pose risks for farmers.

Three farm sizes are considered - small, medium and large. These categories of farms are based on land size, labour and available capital. Formulation of the MOTAD model was accomplished by applying the historical product prices, yields and cost data over an 8-year period to the basic linear programming matrix. The vegetable crops considered in this study are "ladies fingers" (X1), bitter gourd (X2), spinach (X3), "kailan" (X4), long beans (X5) and cucumber (X6).

The solution derived from the MOTAD model shows that the minimum risk farm plans correspond to a certain level of expected income. It provides a range of expected income and risk possibilities and is useful for the understanding of risk associated with the vegetable crop production. This study indicates that the diversification of crops has a major impact on reducing risk and increasing expected income. The farmer, therefore, has a choice in the trade-off between expected income and risk of the farm plans. The farm plan i.e. Plan 8 which projects the highest expected income and risk will be suitable for a risk neutral farmer, that is, maximizing expected return income. Farm plans which have lower gross margins and risks are more suitable for a risk averse farmer.

Thus a farmer's decision on what kind of vegetable crop to grow will depend on his/her attitude toward risks. A farmer with a high risk aversion, and who is not in a financial position to take risks should decrease the planted area of bitter gourd (X2) and "kailan" (X4) and increase the planted area of "ladies fingers" (X1), spinach (X3) and cucumber (X6). In contrast, a risk neutral farmer and farmer with a low risk aversion should grow more high risk crops such as bitter gourd (X2) and "kailan" (X4).

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