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Economics of Risk and Technology Adoption: Evidence from Wheat in Iran

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Abstract

This paper investigates the linkage between new seed varieties (NSV) and production risk and also factors affecting adoption of NSV with an application to a sample of 187 wheat farms in Iran during 2001-2. The risk-premium associated with the use of seed is estimated and the analysis of production risk involves a moment-based approach. Individual risk preferences are used to explain farmer's decision to adopt NSV. The results revealed that NSV is risk-increasing and involves a higher cost of risk and exposure to downside risk has increased by NSV. The farmer-specific relative risk premium proxies for the risk attitudes of each farmer have negative and significant effect on the decision to adopt NSV. That is, the more risk-averse farmers, the less likely to adopt NSV that allow them to decrease their production risk arising from seed requirements.

Keywords: *Production risk, moments-based estimation, wheat seed varieties, Iran*

Introduction

For reasons of food security and agricultural productivity, we need to primarily rely on improving yields of agricultural products instead of expanding cultivated areas or intensifying agriculture through irrigation. Implementing technological change and technology adoption on the farms have contributed to significant increase in agricultural productivity (e.g. Brennan, 1984); however, it has affected production risk (Antle and

Crissman, 1990). Risk has often been considered as a major factor reducing the rate of adoption of any kind of innovation (Roosen and Hennessy, 2003). Saha (2001) believes that greater perception of risk in the cultivation of high-yielding seeds (HYS) compared to the cultivation of traditional seed varieties (TSV) may arise due to many factors. In the early stages, the farmers' perceptions of risk are associated with lack of information of and incomplete learning about new seeds. Moreover, weather and climate conditions have different impacts on various types of seed. It is often found that TSV are more resistant to moisture stress, water level fluctuation and certain pest attacks compared to HYS. Finally, as is also stated by Mehra (1981), it is often argued that uncertainty in the cultivation of HYS is also related to greater use of fertilizer and other purchased inputs, which are believed to have positive marginal risk effect on yield.
Cultivation of HYS has high average yield and high yield fluctuation, i.e. greater risk. Therefore, rational risk-averse farmer allocate their available land between two technologies rather than completely switching to the cultivation of the former. Furthermore, risk associated to the technology is not always related to the HYS technologies but also to the lack of information of and incomplete learning about new technology and farm-specific factors, the matter of which is ignored by most of the previous studies (e.g. Dillon and Anderson, 1971; Just and Pope, 1997; Mehra, 1981; Feder, *et al.,* 1985; Sasmal, 1993 and Panell *et al*., 2000).

Wheat is the main food staple and the core commodity in Iran and the rain-fed and irrigated wheat covers approximately 4.5 million and 2.2 million hectares, respectively. At least 40 percent of Iran’s wheat is rainfed with an average yield of only 0.8 tonnes/ha and even under the irrigated land, the average wheat yield in Iran rarely exceeds 3.0 tonnes/ha. Despite low yield of wheat, and growing consumption of wheat in the country driven by population growth mainly in urban areas, recently Iran has approached self-sufficiency in wheat. Apart from favorable weather in the past two years, the government support for wheat production has played has also contributed towards the bumper results. During the post revolutionary period and basically in recent years, the Iranian government sharply raised spending on wheat farming by various instruments such as supplying higher yielding seeds and enhancing water systems. The guaranteed procurement prices have been raised significantly to increase farmers' incentives and to encourage farmers to produce as much wheat as needed to meet the domestic consumption. However, many small holders, who perform a large portion of total wheat producers in the country, prefer to utilize low yielding seed varieties in their farms and therefore the average yield tend to remain low. This is partly due to their individual characteristics as well as farm-specific factors and also because of risk associated with using HYS.

In this study, we want to evaluate individual risk preferences which along with other explanatory variables can be used to evaluate wheat farmer's decision to adopt new seed technologies. In this context, the main contribution of this paper is that the farm-specific factors that determine the risk of new seeds in practice are considered to study risk comparison of alternative wheat seed technologies in Iran.

Methodology

The methodology used in this study has two steps and is also used by Soltani *et al.,* (2004) and Bakhshoodeh and Shajari (2006) and is partly taken from the procedure developed by Koundouri, *et al.,* (2002). At the first step, the risk-premium associated with the use of new seed varieties (NSV) is estimated by adapting the Antle (1987) and Kim and Chavas (2003) approaches and using a moment-based approach. In the second step, individual risk preferences are derived from the technology and preferences of the farms, which are then used to explain farmer's decision to adopt new seed technologies applying a Probit model in LIMDEP 7.0.

Under risk aversion, decision makers are adversely affected by a higher variance of returns. Also, under downside (skewness) risk aversion, the welfare of decision makers is positively (negatively) affected by an increase (decrease) in skewness of returns. This paper examines the effects of technological change of seeds on the first, second and third moments of wheat profitability, as they evolve under technological progress. The farmer's program can be equivalently written as the maximization of a function of moments of the profit distribution, F(.):

$$\text{Max}: EU(\pi) = F[\mu_1(X), \mu_2(X), \ldots, \mu_m(X)], \quad (1)$$

where μ_j (j = 1, 2, . . . , m) is the j^{th} moment of profit (π) and $\pi = A\times(P\times Y - C)$ in which A denotes acreage of wheat, P is price of output, Y is yield per ha and C is cost per ha of wheat production both depending on input choices X_i (X_1: Acreage of wheat, X_2: nitrogen fertilizers, X_3: phosphate fertilizers, X_4: seed, X_5: number of irrigations, T: dummy variable of NSV, D: dummy variable for years 2001 and 2002), technology *t*, and production uncertainty ***e***.

As is also stated by Pratt (1964) and Hardaker *et al*., (2004), the cost of private risk bearing can be measured by the sure amount *R* satisfying:

$$EU(\pi) = U[E(\pi) - R] \quad (2)$$

where $[E(\pi)-R]$ is the certainty equivalent of profit. *R* is the risk premium measuring the largest amount of money that decision maker is willing to pay to replace the random variable π by its expected value $E(\pi)$. Risk aversion implies that $R > 0$, and corresponds to a concave utility function: $\partial^2 U/\partial\pi^2 < 0$ (Pratt, 1964). In general, the certainty equivalent, $E[\pi(\boldsymbol{X}, t, \boldsymbol{e})] - R(\boldsymbol{X}, t)$, depends on input use $\boldsymbol{X}$ and technology *t*.
In a similar fashion, Kim and Chavas (2003) proposed to investigate the effects of technological change on risk exposure. They indicated that the risk premium can be approximated by:

$$R_1 = 1/(A\ U^1)\ [-\Sigma\ (U^j/j!)\ (A^{j\cdot}\ \mu_{j\pi})] \quad (3)$$

where $U^j = (\partial^j U/\partial\pi^j)(E(\pi))$ is the *j*th derivative of *U* with respect to profit π, evaluated at $E(\pi)$, $j = 1, \ldots, m$ and $m \geq 2$. Note that $\mu_{j\pi}$ is the *j*th central moment of π. Thus, expression (3) provides an approximate measure of the risk premium as a function of the first *m* moments of profit. When $m = 2$ gives the approximation obtained by Pratt (1964).
In order to utilize equation (3) for $m = 3$ and to evaluate the cost of risk, we need to know the decision-maker's risk preferences. Assuming that the decision maker's risk

preferences exhibit constant relative risk aversion, with utility function $U(\pi) = \pi^{1-\lambda}$ when $(1 - \lambda) > 0$, and $U(\pi) = -\pi^{1-\lambda}$ when $(1-\lambda) < 0$, $\lambda > 0$ being the relative risk aversion coefficient (Pratt, 1964), we have equation 4:

$$\partial\mu_1(X)/\partial X_k = \theta_{1k} + \theta_{2k}\, \partial\mu_2(X)/\partial X_k + \theta_{3k}\, \partial\mu_3(X)/\partial X_k + u_k \quad (4)$$

where $\theta_{jk} = -[(\partial F(X)/\partial\mu_j(X))/(\partial F(X)/ \partial\mu_1(X))]\ (1/j!)$, $j = 1, \ldots, 3$ and u_k is the usual econometric error term. θ_{2k} and θ_{3k} are directly related to the theory of decision under risk as $(2\theta_{2k})$ and $(-6\theta_{3k})$ are good approximations of Arrow-Pratt and downside coefficients of risk-aversion respectively. The risk-premium is then derived as RP_k for each k:

$$RP_k = \mu_2 \cdot (AP_k/2) - \mu_3\, (DS_k/6) \quad (5)$$

where μ_2 and μ_3 are respectively measures of the second- and third-order moments of the distribution.

Farmer's attitudes towards risk derived farm-specific relative risk premia are used in the second stage. In particular, they are used to construct the explanatory variable that proxies risk attitudes. This variable is then included in the discrete choice model that explains the probability of technology adoption as a function of risk attitudes, farmer-specific socio-economic characteristics and farm-specific qualitative and financial characteristics.

Data and variables

Farm-level data were collected from a sample of 187 wheat farms located in three major districts of Fars province in Southern Iran: Darab, Fasa, and Sarvestan. The sample was selected by a two-stage cluster sampling during the years 2001 and 2002. The survey provides detailed information on the production patterns, input use, wheat production yields, prices of the inputs and output, social and personality characteristics of farmers and their families, structural characteristics and the number of farms adopting new seed technologies during the studied years.

Descriptive statistics of the major variables of this study are reported in Table 1. As can be seen, 57 farms in Darab (71%), 41 farms in Fasa (66%) and 27 farms in Sarvestan (60%), have adopted NSV during the years of the survey. These farms are of larger sizes and on average are 10, 10.9 and 11.3 hectare in Darab, Fasa and Sarvestan, respectively.

Table 1. Descriptive statistics

	Darab		**Fasa**		**Sarvestan**	
	Adopters	Non-Adopters	Adopters	Non-Adopters	Adopters	Non-Adopters
No of farms	57	23	41	21	27	18
Percent of farms	71.2	28.7	66.1	33.9	60.0	40.0
Yield (ton/ha)	5.4	4.6	5.5	4.6	4.6	3.5
Profit (1000 Rials/ha)	4605	3404	4754	3554	3669	2186
Acreage of wheat	10	7.34	10.9	7.8	11.33	9.4
No of land parcels	2.47	2.5	4.9	3.29	1.67	1.56
Land ownership (% of farmers)	66.7	64.7	42.15	39	73	66.7
Seed (kg/ha)	319.4	365.0	259.5	273.6	265.3	280.8
Nitrogen fertilizers (kg/ha)	631.5	550.1	579.6	380.7	298.9	285.1
Phosphate fertilizer (kg/ha)	237.9	225.0	226.0	209.1	262.5	228.3
Potassium fertilizer (kg/ha)	349.3	295.0	343.5	293.0	339.7	316.7
Applied herbicides (lit/ha)	2.9	2.1	2.0	1.5	1.9	1.3
No of irrigation	7.7	6.8	6.4	5.4	7.3	6.1
Proper cropping date (% of farmers)	23.6	55.0	35.0	48.1	33.3	41.7
Proper rotation (% of farmers)	32.5	50.0	13.2	28.2	16.7	35.5
Farmer's age (years)	47.6	52.9	53.7	58.6	41.8	48.8
Farmer's education (years)	4.4	3.0	8.8	5.7	8.7	6.5
Farmer's experience (years)	30.6	30.5	35.9	37.7	21.7	27.6
Extension visits (No of visits)	3.7	2.8	3.8	2.0	2.6	2.0

In all three regions, farms adopting NSV have higher average yield and profitability per hectare than non-adopting farms. The average irrigation number in farms adopting NSV is higher than that in the non-adopters of the three districts. The farmers adopting NSV intensively use inputs such as herbicides and fertilizers whereas farmers cultivating TSV use more seed. Also, proper date of cropping and rotation as recommended by agricultural research stations found to be lower amongst the former farmers. The cultivation of HYS involves both higher average yield as well as higher yield fluctuation compared to the cultivation of TSV.

On the basis of the data obtained, it is evident that older farmers, who are in general less educated than their younger counterparts, are not eagerly adopting new technologies. The average age and education level of farmers adopting NSV are 47.6 and 4.4 years, 53.7 and 8.8 years and 41.8 and 8.7 years, respectively in Darab, Fasa and Sarvestan, whereas for farmers using traditional technologies the corresponding figures are 52.9 and 3 years, 58.6 and 5.7 years and 48.8 and 6.5 years.

On average, the farmers adopting NSV in Darab, Fasa and Sarvestan respectively participated at extension classes 3.7, 3.8 and 2.6 times, which are higher than the corresponding figures for the other farmers who on average took part in these classes 2.8, 2 and 2 times respectively. The farmers adopting NSV have higher percentage of land ownership than non-adopting group in these regions.

Empirical results

This section explores the implications of NSV and uncertainty on wheat profit in the studied areas. The expected value of profit, its variance and its skewness are specified and estimated as discussed earlier in materials and methods section.

The econometric results presented in Tables 2, 3 and 4 summarize the estimation results for expected profit by NSV farm characteristics and by location (Darab, Fasa and Sarvestan). The coefficients associated with T are statistically significant and have expected signs. These tables report statistically significant and positive relationship between the variance of profit and T. The relative risk premium R_1 was found to increase with T revealing that NSV is a risk-increasing input and involves a higher cost of risk. Based on the tables, the exposure to downside risk has increased by adopting NSV. The variable D is of no significance because the weather conditions in two studied years were similar.

Table 2. GLS estimates of three central moments of wheat profit in **Darab**

	First moment		Second moment		Third moment	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	2.73	1.15^{ns}	1.56	2.49**	1.58	1.81*
X_1	-363.60	-5.34***	-24517.70	-2.66**	-12166.20	-1.76*
X_2	-138.27	-2.17**	-742.19	-1.33^{ns}	-473.79	-1.67*
X_3	112.17	1.95*	-0.71	-0.85^{ns}	423.07	0.87^{ns}
X_4	119.95	1.87*	322.82	2.26**	17.23	1.72*
X_5	122.42	2.31**	-4097.69	-3.06***	-5073.50	-0.53^{ns}
X_1^2	94.81	3.53***	713.59	2.47**	-225.77	-0.95^{ns}
X_2^2	0.51	1.81*	2.17	1.25^{ns}	12.63	1.46^{ns}
X_3^2	-0.44	-2.15**	0.22	1.21^{ns}	-2.058	-1.62*
X_4^2	-0.005	-1.79*	1.23	0.97^{ns}	874.74	1.98*
X_5^2	-0.55	-1.89*	115.67	1.98*	2819.16	1.77*
D	117.07	0.52^{ns}	227.31	0.42^{ns}	79.00	0.78^{ns}
T	2.25	1.93*	3.73	2.87**	-4.91	-1.73*
R^2	0.57		0.34		0.25	

$^{*, ** \text{ and } ***}$significant at the 10%, 5% and 1% levels and ns = non significant

Table 3. GLS estimates of three central moments of wheat profit in **Fasa**

	First moment		Second moment		Third moment	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	29982.58	1.19^{ns}	0.54	2.35**	0.08	1.09^{ns}
X_1	-1387.59	-2.37**	2460.84	1.75*	3003.63	1.93*
X_2	2971.78	1.78*	-292.18	-2.11**	262.64	1.07^{ns}
X_3	-1236.09	-2.28**	1136.67	2.37**	-1479.43	-1.92*
X_4	3424.27	2.49**	298.61	2.22**	673.45	1.83*
X_5	18067.07	1.11^{ns}	5385.24	0.08^{ns}	47777.68	1.38^{ns}
X_1^2	832.32	2.66**	-75.88	-2.31**	-18.80	-1.86*
X_2^2	-0.07	-1.93*	2.26	1.87*	-2.051	-1.15^{ns}
X_3^2	2.27	1.76*	-3.07	-2.28**	4.99	2.03**
X_4^2	-567.69	-2.31**	-769.75	-2.32**	-72.88	-1.89*
X_5^2	-143.51	-1.02^{ns}	415.19	0.09^{ns}	-4712.36	-1.45^{ns}
D	85.26	0.78^{ns}	173.65	0.83^{ns}	21500	0.53^{ns}
T	1.19	1.87*	2.20	2.53**	-4.15	-1.97*
R^2	0.61		0.47		0.22	

$^{*, ** \text{ and } ***}$significant at the 10%, 5% and 1% levels and ns = non significant

Table 4. GLS estimates of three central moments of wheat profit in **Sarvestan**

	First moment		Second moment		Third moment	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	-3.63	-2.08**	0.95	1.94*	0.75	1.76*
X_1	-3836.53	-2.28**	7060.62	1.89*	-684.22	-1.94*
X_2	1358.70	5.09***	-1266.50	-1.87*	-1408.58	-1.45 ns
X_3	-1786.84	-1.8*	453.77	1.35 ns	635.98	1.24 ns
X_4	2686.41	2.88**	-232.15	-1.93 *	1397.71	1.39 ns
X_5	-19162.20	-1.07ns	19095.84	1.12 ns	10533.27	1.03 ns
X_1^2	125.32	1.93*	-181.98	-1.94*	-35.40	-1.78*
X_2^2	-32.58	-4.43***	2.39	1.56 ns	3.10	1.36 ns
X_3^2	5.78	2.47**	-0.42	-1.18 ns	-1.09	-1.24 ns
X_4^2	-1054.72	-2.46**	1197.12	2.85 **	-1142.01	-1.43 ns
X_5^2	571.53	1.03 ns	-4238.94	-1.36 ns	-3073.78	-1.13 ns
D	273.19	1.18 ns	351.73	0.76 ns	479.15	0.91 ns
T	-0.85	-1.88*	0.42	185 *	-2.73	-2.67**
R^2	0.67		0.37		0.22	

*, ** and *** significant at the 10%, 5% and 1% levels and ns = non significant

We also examined the statistical significance of T on the relative risk premium by regressing relative risk premium on the T at each mentioned district. The relationship between relative risk premium and T are presented in Table 5.

Table 5. Relationship between relative risk premium and NSV in studied areas

	Constant	T	R^2
Darab	0.85 (0.54) *	1.13 (0.48) **	0.78
Fasa	0.53 (0.31) *	1.24 (0.55) **	0.65
Sarvestan	0.79 (0.35) **	1.36 (0.75) *	0.57

Standard errors are in parentheses.
* and ** significant at the 10% and 5% and 1% levels.

The coefficients associated with T are statistically significant and have expected signs indicating that T is a risk-increasing input in the studied areas.

Table 6 reports the estimation results of the risk-aversion measures. The θ_{2k} parameter associated with the second moment (variance) of profit is positive and significant, which indicates that farmers exhibit Arrow-Pratt risk aversion, i.e. they are willing to sacrifice a proportion of their expected profit in order to avoid the risk associated with seed input in their production.

Table 6. Estimation results of the risk-aversion measures

	Constant	θ_{2k}	θ_{3k}	R^2
Darab	-0.073 (0.044) *	3.15 (1.72) *	-2.08 (0.88) **	0.71
Fasa	-0.64 (0.386) *	2.26 (1.28) *	-2.16 (0.94) **	0.77
Sarvestan	0.92 (0.413) **	1.13(0.61) *	-1.90 (1.02) *	0.63

Standard errors are in parentheses.
* and ** significant at the 10% and 5% and 1% levels.

The coefficient linked to the third moment (skewness or downside risk) of profit is negative and significant, revealing that farmers also exhibit down-side risk aversion and so they are risk averse to a profit distribution that is skewed towards negative values.

Risk comparison of alternative seed technologies

Risk associated to alternative seed technologies in wheat cultivation is examined in this study by farmer-specific relative risk premium proxies for the risk attitudes of each farmer and through several scenarios. Table 7 reports the relative risk premium for alternative high-yielding NSV and traditional varieties TSV of wheat in the studied areas. To create a representative scenario, D_1 and D_2 are set to zero referring respectively to traditional irrigation method and improper date of planting.

Table 7. Relative risk premium of alternative seed technologies scenarios

Scenario	Relative risk premium	
	Cultivating of NSV	Cultivating of TSV
D_1=0 and D_2=0	3.65	2.77
D_1=1 and D_2=0	2.31	2.59
D_1=0 and D_2=1	1.88	2.35
D_1=1 and D_2=1	1.76	2.27

Table 7 indicates that when D_1=0 and D_2=0, the cultivation of TSV have a lower relative risk premium than cultivating NSV. This means that cultivation of TSV is a less risky input than cultivating NSV. This is in a reverse direction if production conditions are proper (e.g. when D_1 and/or D_2 equal one and refer respectively to modern irrigation method and/or proper date of planting.

Determinants of NSV

In this section, the relative risk premium is used to the estimation of the choice model in order to investigate whether risk attitudes affect the decision to adopt NSV. Table 8 represents effects of corresponding variables on the decision to adopt new seed technologies that are achieved from running a Probit model.

Table 8. Estimates of the Probit model

	Coefficient	Standard Error
Constant	1.170	1.390 ns
Farm's size	0.087	0.040*
Farmer's age	-0.160	0.090*
Farmer's education	0.130	0.081*
Farmer's experience	0.150	0.303 ns
Land ownership	-0.043	0.051 ns
No. of land parcels	-0.028	0.061 ns
Participation times at extension classes	0.427	0.233 *
Production cooperative membership	0.061	0.075 ns
Farm's debt ratio	0.914	0.417**
D_1	0.796	0.684 ns
D_2	0.673	0.468 ns
Relative risk premium	-0.270	0.125**
McFadden's R^2	0.311	

*, ** and *** significant at the 10%, 5%and 1% levels and ns = non significant

The value of the derivatives was calculated at the mean values of all the independent variables that are shown in Table 9 and represent the marginal effects of each regressors and approximate changes in the probability of adoption at the regressors' means.

The results show that the farmer-specific relative risk premium proxies for the risk attitudes of each farmer have a negative and significant effect on the decision to adopt NSV. That is, farmers that are more risk-averse with respect to their use of seed are less likely to adopt NSV that allow them to decrease their production (yield) risk arising from seed requirements. Farmers with higher debt ratio are more likely to adopt the new technologies. The participation of the farmers in extension classes has significant effect on the probability to adopt the new technologies. This maybe attributed to the fact that extension classes are more related to high yield varieties.

Table 9. Marginal effects on the probability of adoption

Variables	Coefficient	Standard Error
Farm's size	0.031	0.035 ns
Farmer's age	-0.057	0.030*
Farmer's education	0.047	0.021**
Farmer's experience	0.054	0.117 ns
Land ownership	-0.015	0.679 ns
No. of land parcels	-0.010	0.021 ns
Participation times at extension classes	0.153	0.085*
Production cooperative membership	0.022	0.024 ns
Farm's debt ratio	0.329	0.172*
D_1	0.286	0.196 ns
D_2	0.242	0.187 ns
Relative risk premium	-0.097	0.043**

*, ** and *** significant at the 10%, 5%and 1% levels and ns = non significant

As indicated in Table 9, the more educated the farmers are, the higher the probability that they adopt new technologies, while the older the farmers, the less inclined they are to adopt NSV.

Policy implications and recommendations

The results in this study showed that the risk premium increases with NSV in the lack of proper production conditions. This implies that NSV are a risk-increasing input that involves a higher cost of risk and exposure to downside risk increases by these varieties. This consists with the view that modern seed-fertilizer technology involves greater risk compared to traditional cultivation. Due to many studies (e.g. Antle, 1983; Dinar, and Yaron 1992; Droogers, et al., 2000; Isik and Khanna, 2003 and Hardaker et al., 2004), risk has often been considered as a major factor reducing the rate of adoption of any kind of innovation. However, comparison of traditional and new wheat varieties in this study indicated that under proper production conditions, the cultivation of new wheat varieties ensures greater yield than in traditional wheat varieties on average and also involves less risk as measured by the risk premium. So, previous studies that indicated NSV is a risk-increasing input considered the cited technologies independent of the pertinent technical factors, and of the dominant conditions ruling over the farms concerning the adoption of these technologies. Findings also indicated that the farmer-specific relative risk premium proxies for the risk attitudes of each farmer have negative and significant effect on the decision to adopt NSV. That is, farmers that are more risk-averse with respect to their use of seed are less likely to adopt NSV that allow them to decrease their production risk arising from seed requirements. These findings are accordance with those of Bakhshoodeh and Shajari (2006) in a similar study on adoption of new rice seed varieties under production risk in Iran.

In general, because HYS are more sensitive to farm-specific factors than TSV to reduce production risk arising from seed requirements, diffusion and learning, education and extension about proper application of NSV according with pertinent technical factors and of the dominant conditions ruling over the farms for preparing relevant production conditions is recommended.

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