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Factors Affecting Repair Costs of Small Tractor Use in Riau Province, Indonesia

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Factors affecting annual repair costs were analyzed and a reasonable function was proposed by including more explanatory variables than the previous models for small tractors. Data used in this study was based on a survey of 62 tractors from three selected regencies in Riau Province in 2003. As a result, tractor age, usage, horsepower and operator skill were statistically significant explanatory variables, whereas the ownership system and manufacturer weren't. Using the proposed model, the annual repair costs were estimated to increase during the expected life of tractors. Changes in usage, horsepower, and operator skill increased more rapidly for annual and cumulative repair costs over the tractor lifespan. Of the significant variables, the effect is more pronounced for operator skill variable. The results suggest that priority should be given to operator training and selection.

Keywords: Annual repair costs, small tractor, cumulative repair costs, model

Of the 103,445 of the country's total small tractors in 2002, 650 (6%) are to be found in Riau Province (Central Bureau of Statistics, 2003). The number has increased by more than double from 242 tractors in 1998 (Statistical Bureau of Riau Province, 1999). Of the 116,433 ha rice harvested area in the province, only about 22.3% can be worked by machine, while the remaining 77.7% is worked by using both hand-tools and drought-animal. The remarkable progress of the tractor use has been encouraged very much by the government through the ministry of agriculture, which introduced a farm mechanization scheme to small farmers and demonstrated the advantages of the tractors for rice farming.

Changes in the level of mechanized farming from hand-tools and drought-animal technology to tractor had a significant effect on crop production costs. Kampe (1971) claimed that one-third of the expenses of growing a crop will be vested in machine operating costs. In area of cost for the tractor operations, repair and maintenance costs (henceforth referred to as repair costs) have become increasingly significant. Survey showed that approximately 53% of total machine costs in developing countries were for repairs (Inns, 1978), while in developed countries this was lower accounting for about 25% in the UK (Morris, 1988) and 8% in the US (Fairbanks *et al*., 1971).

It is important for farmers to accurately know the repair costs mainly for farm budget accounting purpose. When farmers have no complete records of the actual repair costs, a prediction should be made. The problem is that the repair costs are practically difficult to estimate (Kepner *et al*., 1980; Finner and Straub, 1985) because of highly variables (Beppler & Hummeida, 1985) unless actual records have been maintained (Jacobs *et al*., 1983). The variability of the repair costs results from the machine breakdowns which are highly random in nature (Hunt, 1971). Although it is not an easy job, the repair costs have been tried to be predicted by using several methods, which are commonly more applicable to the finite use situation.

The important concept in making a reasonable prediction is to understand in detail which factors affect the repair costs and how the costs increase over the machine's life. The most common theory reveals that repair costs increase with increasing use (machine age)

(Puzey & Hunt, 1968, Bowers & Hunt, 1970; Fairbanks *et al*., 1971; Hunt, 1983; Ward *et al*., 1985; Morris, 1988, Bukhari *et al*., 1988; Ahmed *et al*., 1999). Besides increasing with age, the repair costs also increased in the larger engine power of machines (Al-Suhaibani and Wahby, 1999). Most of them proposed a simple method for estimation purpose, which related the cumulative repair costs to accumulative use (in hour). A commonly used method to find the best function is the power or linear function.

With regard to the accuracy of the functions, most of them suggested that the derived functions were useful as a general guide. The functions could not accurately predict repair costs for any one machine because of wide variations resulting from differences in operator skill and attitude, machine design features, maintenance management, climatic and soil factors, operating practices and inherent machine defects, operation type and working conditions, and availability of spare parts. These factors were ignored in the previous functions, but recognized to have an effect on the repair costs estimation. Operator skill, for example, was found to be a major factor influencing tractor repair costs (Morris, 1988).

Understanding how the repair costs are affected by many factors is crucial in making a reasonable estimation. Thus, methods for predicting the repair costs should include factors affected the costs as many as possible in the model. Therefore, this study attempts to include more additional explanatory variables than the previous models, namely age, usage, engine horsepower, operator skill, ownership, and tractor make. The objective of this study is to examine the effect of each above variables on annual repair costs and to develop a reasonable repair cost model, and to attempt the possible use of the model for specific application for this study.

Development Model

The estimation of the annual repair costs requires the specification of a functional form. Consistent with previous studies, the increase pattern of tractor repair costs is denoted by a function, f, that relates the annual repair costs, *RC*, to tractor age, *A*, number of annual use, *U*, engine horsepower, *H*, and three binary variables of operator skill, S, ownership system, O, and manufacturers, M. The functional relationship is then written as follows:

$$RC = f(A, U, H, S, O, M) \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

In order to operationalize (1), it is necessary to choose an applicative model for this study. A translog model of the multiplicative power function form (popularly called the Cobb-Douglas functional form) is chosen because the model is assumed to be consistent with the pattern of increasing repair costs that aren't at a constant rate. The model is expected to follow the behavior of increases of repair costs over the machine's life. Thus, we can apply ordinary least squares (*OLS*) techniques. By adding the stochastic disturbance term, ε, the economic specification of the translog model is generally expressed as follows:

$$\ln RC_t = \alpha_0 + \sum_{i=1} \beta_i \ln X_{it} - \sum_{j=1} \gamma_j D_{jt} + \varepsilon_i \quad \ldots(2)$$

where $\alpha_0 = \ln \alpha$. X_{it} represents transformed variables of *A*, *U*, and *H* with the corresponding coefficient β_i. The annual repair costs are expected to increase with the *A*, *U*, and *H* increase. D_{jt} represents all dummy variables not transformed (*S*, *O*, and *M*) with the corresponding coefficient γ_i. The binary skill variable is 1 if skilled operator or 0 unskilled operator. The moving of tractor operators from unskilled to skilled is hypothesized to be lower repair costs. The tractor ownership system is 1 for the group ownership or 0 for the individual ownership. The manufacturer dummy variable is 1 if manufactured by Yanmar or 0 for other manufacturers. The α, β_i, and γ_i are unknown parameters yet to be estimated.

By using estimated annual repair costs, cumulative repair costs (*CRC*) can be estimated by:

$$CRC = \sum_{i=1}^{n} RC_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where: i = 1, 2, 3 …n

Sources of Data

Data used in this study is collected via surveys in three regencies of Riau province, they are Kuantan Sengingi, Rokan Hulu and Siak, from October to December 2003. Sixty-two tractors were randomly selected in the regencies and the owners were interviewed personally using a questionnaire. Data colleted included year of tractor purchase, engine horsepower, tractor make, ownership system, number of hectare use, and operator training and repair costs. The repair costs consisted of regular services and repairs, replacement of miscellaneous parts, labor charge, and other maintenance needs. The data then is tabulated to make ready as input data for computerized analysis and the process was helped by *KyPlot* statistical package.

Results and Discussion

The largest portion of the samples was Yamnar tractors (55%), followed by Kubota tractors (29%), and other makers (16%). The engine horsepower ranged from 7.5 to 10.5 hp with 8.5 hp being the most popular. Typical tractor age varied from 1 to 12 years with an average of 4.7 years old. About 52% of the tractors were individually owned, which were purchased new from dealers and 48% were organized into group farmers, which were obtained from government aid through the Minister of Agricultural mechanization scheme for small rice farmers.

Tractor operators consisted of the owners, relatives or hired operators. Most operators learned their craft from others rather than training institutions. Only 27% of the operators received short government-sponsored training. While the education level of the operators was mostly elementary school (44%), follow by secondary school (27%) and high school (23%). The remaining 6% had no formal education.

The tractor works concentrated on land preparation for rice growing, including plowing and pulverization operations. Most tractors operated twice a year following during cropping patterns. The seasonal work ranged from 20 to 55 days with an average of 52 days. The annual use ranged from 5 to 40 ha with the average being 21.4 ha. The average annual use is equivalent to 458 h/year under working time of 22 h/ha on average.

Of the total repair costs, about 95% was spent on repair, while 5% was spent on maintenance. An expensive repair item was to purchase replacement parts (81%) and labor charge to make repairs was 14%. The high price of spare parts and materials contributed to the high cost of replacement parts. The amount spent on repair costs based on tractor age and usage ranges is presented in Table 1.

It is clear that the annual repair costs increased as tractors became older and added more hectares of use. The results are in agreement with other sources (Fairbanks *et al*, 1971; Henderson & Fanash, 1984; Ward *et al*, 1985; Al-Suhaibani & Wahby, 1999). In addition, the results indicate that there are not large variations occurring in the annual repair costs from one machine to another at the same age, as shown by the low value for the coefficient of variation (cv).

Estimation Results

Estimation results are summarized in Table 2. Parameters were estimated by Equation (2) in natural logarithms form using *OLS* method. The coefficient determination (Adjusted R^2 = 61) is moderately high. Simultaneously, all independent variables have a statistically significant at 99.9% confident level. Partially, all estimated coefficients except two of the dummy variables were significant at a range from 95% to 99.9% confidence levels.

The signs of the estimated parameters are consistent with our expectations. The positive signs of β_1 *and* β_2 indicate that as the age and usage increase, the annual repair costs increase. Similar signs of coefficient regression were found for horsepower variable which means that the annual repair costs increase with larger engine horsepower. The dummy variable of the operator skill showed highly significant. This result implies that the annual repair costs of tractors have a significantly difference between skilled and unskilled operators.

Table 1 Annual repair costs with different age and annual usage

Age range (years)	Number of tractors	Repair costs (Rp000)	Coefficient of Variation (CV)	Usage range (ha)	Number of tractors	Repair costs (Rp000)
1	4	41	61	0 – 4	-	-
2	9	358	62	5 - 8	9	174
3	7	485	54	9 – 12	6	304
4	13	421	87	13- 16	5	346
5	5	458	59	17 – 20	9	727
6	8	454	71	21 – 24	5	716
7	6	684	59	25 – 28	9	562
8	5	614	46	29 – 32	13	751
9	2	1,619	79	33 – 36	1	190
10 and above	3	2,099	12	37 - 40	5	1,653
Total	62				62	

Note: Rp1000 is equivalent to about U.S.$0.118 according with an average of exchange rate in 2003

Table 2 Results of the estimated parameters for the regression model

Variable	Parameter	Coefficient	Standard Error	*t*-Statistic
Intercept	α	5.763**	1.894	3.041
Age	β_1	0.946***	0.161	5.859
Usage	β_2	0.657***	0.173	3.804
Horsepower	β_3	1.786*	0.872	2.048
Operator skill (Dummy)	γ_1	-0.753**	0.221	-3.414
Ownership (Dummy)	γ_2	0.045	0.217	0.208
Manufacturer (Dummy)	γ_3	0.033	0.199	0.165
R^2		0.649		
R^2-Ajusdted		0.611		
F-Statistic		16.960***		
Number of sample		62		

*** Denotes statistical significance at the 99.9% confidence level
** Denotes statistical significance at the 99% confidence level
* Denotes statistical significance at the 95% confidence level

The ownership and manufacturer dummy variables are not significant. It means that there is no significant difference in the annul repair costs between the two ownership system or among manufacturers. No significance of ownership system is proven by the fact that general maintenance procedure practiced between group and individual owners was almost indifferent. They also rarely received advice from agricultural extension officers or dealer experts. A detailed printout of statistical results is available from the authors.

Application Model

In order to make a reasonable prediction, insignificant variables are excluded from the model through variable selection using stepwise forward method. The reduced form model of the annual repair costs function in logarithmic linear form is as follows:

$$RC_t = 5.669 + 0.955 \ln A_t + 0.671 \ln U + 1.820 \ln H - 0.744S \quad \text{with } \bar{R}^2 = 0.624$$
$$(6.151) \quad (4.179) \quad (2.221) \quad (-3.484)$$

……………...…...(4)

and *t*-statistic is in parenthesis.

Here RC_t is the estimated annual repair costs in a year t; A_t is the year of age of the tractor in year t; *U* is the average hectare of use per year; *H* is the engine horsepower; and S is the dummy variable for operator skill.

To facilitate an application in this study, reduced form model of the annual repair costs is formulated into exponential form:

$$RC_t = 290(A_t)^{0.96}(U)^{0.67}(H)^{1.82}e^{-0.74S} \qquad \text{……(5)}$$

As an example application of the use of model, we set up 21 ha of annual use (according to average use in data set), 8.5 hp (the most tractor samples available), tractor was operated by skilled operators, the estimated result during a period of 12 years (according to the oldest tractor in this study) is shown by base estimates in Figure 1. The results show that the annual repair costs increase each additional year of the machine's life. With regard to the curve of the base estimates, the annual repair costs increase from Rp53 thousand in the first year to Rp576 thousand at the end of the 12th year. This means that the costs increase ten fold during a period of 12 years with an additional increase of Rp48 thousand annually on averages.

Figure 1 also illustrates the estimated annual repair costs as effect of usage, engine horsepower, and operator skill during the expected life of the tractor. When all other variables held constant, an increase in hectares of use from 21 to 40 per year (according to the highest annual use in this study) leads to higher repair costs over time. The average increase of the annual repair costs is Rp73 thousand per year and the cost will be Rp875 thousand or 52% higher than the base scenario at the end of 12th year. The result suggests that the repair costs are suspected to increase more rapidly for heavier-used machines. By using 10.5 hp tractors, the annual increase would be Rp65 thousand on averages, so the estimated annual repair cost reaches Rp774 thousand at the same year or 34% higher than the base estimates.

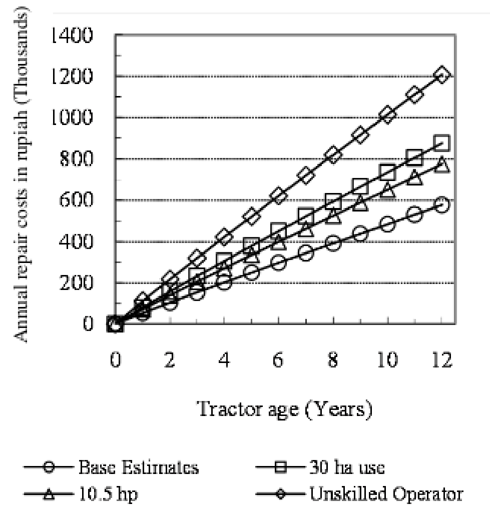

Figure 1 Repair Cost Estimates with Changes in Hectare of Use, Horsepower, and Operator Skill

As outlined above, the operator skill is a dummy variable that is statistically significant. The estimate shows that moving from skilled to unskilled operators increases the annual repair costs from Rp111 thousand in the first year to Rp1.21 million in the 12th year. This increase is more than two times compared to the base scenario with the average annual increase being Rp101 thousand per year during the period. The result implies that the annual repair costs increase at the highest rates when using unskilled operators. The result reflects that human factor may be a major cause of tractor breakdowns. It is important to emphasis the training of the tractor operator in order to achieve substantial saving in repair costs.

Based on the estimated annual repair costs, cumulative repair costs throughout the expected life of the tractor can then be predicted by Equation 3. By using similar scenarios, the estimated results, which are expressed as a percentage of the purchase price (%P), are illustrated in Figure 2. The tractor purchase price is assumed to be about Rp15.5 million (U.S.$1,824) for 8.5 hp tractors. Beginning with lower rates during the first few years, all estimates increase rapidly in later years. The cumulative repair costs would be about 25% of the purchase price at the end of the 12th year for base estimates with an annual increase of about 2.1% per year on average. The increasing rates are about 3.1% and 2.6% on average with the high level of use and larger horsepower, respectively. Consequently, the cumulative repair costs (%P) would be about 37% for 40 ha of annual use and about 31% for 10.5 horsepower at the end of the 12th year. When unskilled operator is assumed, the cumulative repair costs would reach about 52% of the purchase price in the same year with an annual increase of 4.3% on average. Compared to base estimates, this rate is about 27% higher at the end of the 12th year.

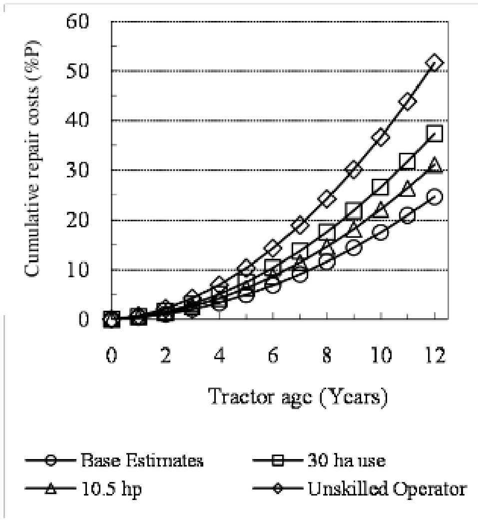

Figure 2 Cumulative Repair Cost Estimates in Percentage of the Tractor Purchase Price (%P) with Changes in Hectares of Use, Horsepower, and Operator Skill

The lower rates of cumulative repair costs during the first few years of life are due to the tractors only requiring minor repairs and replacement of simple parts. The repair and part replacement thereafter is required more frequently; therefore the repair costs had also substantially increased. Interviews with farmers revealed that tractors firstly required engine overhaul after 3 or 4 years. Bukhari *et al.* (1988) reported that the repair costs as percentages of the total costs was more than double in the age group of 2 to 4 year old tractors and again it was double when the age of the tractor was 10 years.

The reasonable function proposed in this study provides a useful model to predict the annual repair costs for small tractors. An attempt to use the model for estimation purposes, a person must be aware that the function may be more applicative for the same type of tractors and similar conditions. It is important to note that there are other factors that aren't considered here, but may have substantially influence on the rates of the repair costs and eventually make different results. They are climatic and soil factors, operation type and working conditions, maintenance regime, operating practices and inherent machine defects, and availability of replacement parts.

Conclusions

The annual repair costs were statistically affected by age, hectare of use, horsepower and skill of operator. Ownership and manufacture variables were not significant explanatory variables in this analysis. A reasonable function was proposed to predict the annual repair costs. The annual repair costs were predicted to increase each additional year of the machine's life. The higher levels of annual use and larger horsepower rapidly increased repair costs to average Rp73 thousand and Rp65 thousand per year, respectively. The annual increase would be Rp101 thousand on average under unskilled operator. The cumulative repair costs as a percentage of the purchase price also were estimated to increase at an increasing rate throughout the tractor's life. The average increase of the accumulative repair costs is about 2.1% per year under 8.5 hp, 21 ha of annual use, and skilled operator. The increasing rates average about 3.1% and 2.6% per year for the higher level of use and larger horsepower, respectively. The cumulative repair costs increase at the highest rate of 4.3% every year in average with an unskilled operator. The great effect of operator skill on repair cost implies that priority should be given to training and operator selection process.

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