Analysis of Attributes Relating to Custom Software Price

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***Abstract*—Price of custom software is very important for a user (end user company). However, there is very little information which helps the user judge the validity of the custom software price. So, one of our research goals is building price estimation model and showing its accuracy for the user to judge the validity of the custom software price. The other goal is how to get value for money custom software. In the analysis, we used 31 projects collected from Japanese organizations. First, we analyzed relationships of unit price of effort, unit price of FP (function point), and productivity. The analysis result showed productivity is more important variable than unit price of effort for the custom software price estimation. Next, relationships of other variables were analyzed to identify important variables for the price estimation. The result suggested some variables such as system architecture are important for that. At the end, the price was estimated based on FP and effort. In the analysis, when the price was estimated based on FP, the median balanced relative error (*BRE*) was 86.6%, and when it was estimated based on effort, median *BRE* was 20.2%.**

Keywords-price; estimation; asymmetric information; unit cost;

I. INTRODUCTION

Price of custom software is very important for a user (end user company). Generally, the user uses package software and custom software. Versatile software such as word processor or spreadsheet software is made as package software, and the user buys it on the market. Custom software is highly specific software which is made to fit workflow of each user, and the user orders custom software to a developer (software development company). In Japanese end user companies, rate of custom software is 38.7%, rate of used package software is 28.1%, and rate of in-house developed software is 33.2% [12]. That is, custom software is most important for the user.

Various package software made by various developers is sold on many stores. So, the user can judge the validity of purchase price of software, comparing functions and prices of the software with others on the market. On the contrary, the user does not know functions and prices of software used in other users' organization. Therefore, the user cannot compare functions and prices of custom software with others, and it is difficult to judge the validity of the custom software price.

Nature of custom software price is similar to building price. It is difficult for a purchaser to judge the validity of building price because each building has high individuality. In public works, to judge the price of building, the standard of cost estimation method and unit price is defined by Japanese Government and local government. Based on the standard, the valid price (standard contract price) is settled before public works building is developed. On the contrary, there is very little information which helps the user judge the validity of the custom software price.

Also, the uncertainty of the custom software price may affect the economic efficiency of the society. As stated above, the user has not enough information of the price. It is called asymmetric information in economics. Asymmetric means that the user has poor information of software but the developer has rich information. The user cannot reach the optimal price because cost and time to search the price are limited [18]. As a result, the trading price (i.e. cost-effectiveness) become different on each trade, and that causes imperfect competition (Software whose price and quality is not balanced is saleable, i.e., some users buy such software). Minimizing the difference (i.e. balancing price and quality) will shift the economy from imperfect competition to perfect competition (Software whose price and quality is balanced is more saleable), and that promotes economic efficiency. To minimize the difference, the information about the custom software price is needed.

One of our research goals is building a price estimation model and showing its accuracy for the user to judge the validity of the custom software price (Note that our research goals are not building the model for the developer to settle the price, and therefore the model is not optimized for the developer). The other goal is how to get value for money custom software. To achieve the goals, we set research questions as follows:

- RQ1: To get value for money custom software, what should the user pay attention to?
- RQ2: Which variables should be used to build a price estimation model?
- RQ3: How much is estimation error of the price when the price is estimated simply by multiplying a variable such as functional size by a constant?

RQ1 is set for the latter goal (the way of getting value for money software). RQ2 is set for the former goal (building the estimation model). We do not build the price estimation model yet. The answer of RQ2 will be useful to build the model. RQ3 is also set for the former goal. Instead of the model, we used simple estimation method and analyzed its estimation error. Note that we did not show the constant of the simple method, to avoid abusing the result.

Section 2 describes dataset used in the analysis. Section 3 explains preliminary analysis of relationships of price, function point (FP), and effort. In Section 4, relationships of unit price of effort, unit price of size, and productivity are analyzed. In Section 5, the price is estimated based on FP and effort. Section 6 explains related works, and Section 7 concludes the research.

II. DATASET

The dataset used in the analysis was collected from 114 Japanese organizations by Economic Research Association [6]. The dataset includes 163 software development projects, and the range of employees of organizations is from several to about 40,000 people. Variables in the dataset have missing values. To align conditions of analyzed projects, we selected new development projects which performed basic design, detailed design, coding, integration test, and system test. After the selection, we eliminated projects where actual effort, actual function point (FP), or price were missing. As a result, we chose 31 projects.

The dataset including custom software price collected from various organizations is very rare and valuable. If the dataset collected from few organizations is analyzed, the analysis result may be affected by individuality of the organizations such as payroll system or profits. Although we analyzed only one dataset, we think the analysis results have generality to some extent because it is cross company dataset.

Variables included in the dataset are as follows:

- User classification: affiliated company of the developer = 0, non-affiliated company of the developer = 1 (the developer is not an affiliated company of the user).
- Contract classification (basic design phase): mandate = 0, contract for work = 1.
- Effort, function point (FP; a metric of software size), and duration (estimated and actual value).
- Error of effort, error of FP, error of duration: (actual value - estimated value) / actual value.
- System architecture: Web based system = 0, client server system = 1.
- Operating system of the server: Linux = 0, Windows 2000 = 1, other OS = missing value.
- ILF/FP, EIF/FP EI/FP, EO/FP, EQ/FP: actual value / actual FP (ILF, EIF, EI, EO, and EQ are element metrics of FP).
- Screen/FP, report/FP, file/FP: number of the element in the custom software / actual FP.
- Price: price which the developer regarded as valid price.

We defined ILF/FP, EIF/FP, EI/FP, EO/FP, and EQ/FP. Values of ILF, EIF, EI, EO, and EQ increase in proportion to FP. So, ratios such as ILF/FP may be more preferable than values such as ILF, to emphasize features of custom software. We also defined screen/FP, report/FP, and file/FP for the same reason.

In the dataset, variable "price" is not actual price, but valid price which the developer regarded as. Actual price is affected by the relationship between the user and the developer. So, using the valid price is more preferable than the actual price, considering the research goal (validating custom software price).

There is not an understanding of the error margins reported in the dataset. To verify the dataset as correct, we confirmed actual effort and actual FP did included abnormal values. In addition, we verified price using unit price (described in section 4). In preliminary analysis, we made an effort estimation model using the dataset and the model showed relatively high estimation accuracy. So, we think the dataset does not include low quality data very much.

III. PRELIMINARY ANALYSIS OF PRICE, FP, AND EFFORT

A. *Selecting explanatory variables*

As preliminary analysis to answer RQ1, we analyzed relationships between the price and actual effort, and the price and actual FP. The reason of selecting FP is as stated below. One of our goals is building the price estimation model for user to judge the validity of the price. So, considering usability, it is not good for the user to use many variables to judge the validity, or to use variables whose values are difficult to know for the user. We regarded FP as the fittest variable to the conditions.

In contrast, the developer can settle custom software price based on rich information such as estimated ratio of each development phase, ratio of staff of each rank such as project manager and programmer, and estimated effort. However, the user does not know such information generally, and therefore the model should not include variables including such information. Note that preliminary analysis showed that ratio of each development phase and ratio of staff of each rank did not relate to the price explicitly.

The reason of selecting effort is as stated below. One of the major pricing methods is cost-plus pricing, which sets sum of cost and profit as price. We assumed that price of custom software is settled by the method in many cases, and therefore, if effort is roughly same as cost, effort has a strong relationship to the price. Although the user does not know effort, the analysis results clarify the followings:

- If the relationship is not very strong: cost-plus pricing is not used widely, or other variables such as

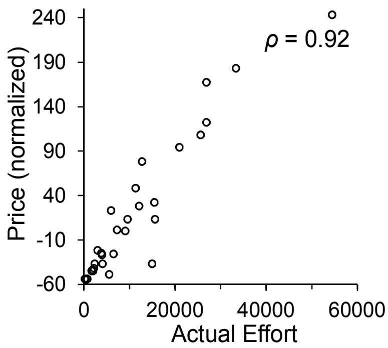

Figure 1. The relationship between the price and actual effort.

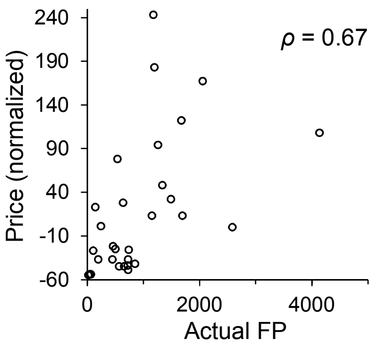

Figure 2. The relationship between the price and actual FP.

unit price of staff and profit of each developer are affected to the price to some extent.

- If the relationship between effort and the price is strong: variables such as unit price of staff and the profit do not affect the price greatly.

B. Analysis results

To analyze relationships of the variables, we used Spearman's rank correlation coefficient and scatter plots. Fig. 1 shows the correlation coefficient ρ and the scatter plot of the price and actual effort, and Fig.2 shows that of the price and actual FP. A data point whose price was very high was eliminated from the figure (Note that it was not eliminated when the correlation coefficient was calculated). The price in the figure is not actual price, but calculated by subtracting median from actual price.

The correlation coefficient between the price and actual effort was very high, and the strong relationship was also observed in the figure. That is, effort has strong relationship to the custom software price. The relationship between FP and the price was strong to some extent. However, it is not easy to judge the validity of the price by FP only, because the diffusion of data points was not small (the relationship between the price and FP is not very strong). Both relationships were statistically significant at 0.05 level.

The analysis result (the very strong relationship between the price and actual effort) is not exactly obvious, even if sum of cost and profit is set as the price by the cost-plus pricing method. Effort does not correspond to cost completely. The dataset includes projects in small companies and large companies, and therefore payroll system or workload of back-office section may be different for each developer. So, there was a possibility that actual effort did not relate to cost strongly. In addition, ratio of staff of each rank such as project manager and programmer appear to be different for software (especially when the number of staff is not large), and it might weaken the relationship between actual effort and cost. Profit added to the price may different for each developer, and there was a probability that it weakened the relationship.

Considering the strong relationship between actual effort and the price, above factors do not seem to affect the price strongly. A major finding of the preliminary analysis is that effort is roughly same as the custom software price, and analyzing the price without above factors is reasonable. Also, the result suggests that detail task information which the developer uses on WBS (work breakdown structure) based estimation is not necessary to judge the validity of the price, because effort (without the detail task information) explains the price very well.

IV. Analysis of Unit Price of Effort, Unit price of Size, and Productivity

A. Definition of ratio variables

Using two variables whose relationship was strong, one variable was divided by the other variable, and new ratio variables were defined. New variables are as follows:

- Unit price of effort: price / actual effort
- Unit price of size: price / actual FP
- Productivity: actual effort / actual FP

Note that the productivity is the reciprocal of the common definition [11] (It is also called project delivery rate (PDR)). We identified two data points whose unit price of effort is smaller than 1,500 yen as outliers, and removed them from analyses.

Generally, on a software project dataset, the strong relationship is approximately denoted as follows:

$$y = a\,x \tag{1}$$

$$y = x^{b} \tag{2}$$

In the equation, x and y are the variables, and a and b are constants (Error term is not included in the equation). When Spearman's rank correlation coefficient is high, both relationships are possible. When the two variables have the latter relationship, dividing one variable by the other variable does not become constant value.

The aim of the analysis in this section is to analyze relationship between price, effort, and FP in more detail. Using the new variables enable detail analysis. For instance, using unit price of size, we can analyze whether the unit price of size varies or not when the price becomes higher. It cannot be confirmed by the preliminary analysis. The aim of the preliminary analysis is to confirm influence of factors such as the unit price of staff and the profit.

TABLE I. THE CORRELATION COEFFICIENTS OF THE PRICE, FP, AND THE RATIO VARIABLES

	Price	Actual FP	Unit price of effort	Unit price of size
Unit price of effort	0.18 (0.36)	-0.27 (0.16)		
Unit price of size	*0.55* (0.00)	-0.15 (0.45)	*0.49* (0.01)	
Productivity	*0.55* (0.00)	-0.08 (0.68)	0.17 (0.38)	*0.93* (0.00)

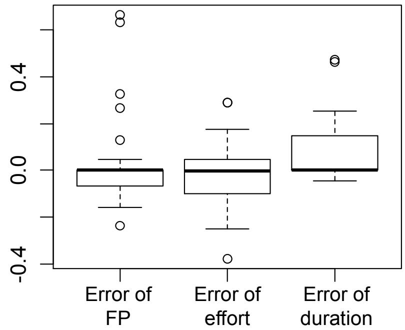

Figure 3. The variances of the errors.

B. Relationships of the ratio variables

The correlation coefficients of variables are shown in Table 1. Italic face means the relationship was statistically significant at 0.05 level. P-values are shown in parentheses. Major observations are the following:

- The relationship between the price and unit price of effort was weak. So, unit price of effort is not discounted (cost-effectiveness is not greatly changed), regardless of the price.
- The relationship between FP and unit price of size was weak. This means that unit price of size is not discounted (changed) much, regardless of FP.
- Unit price of size (i.e. cost-effectiveness) related to productivity more strongly than unit price of effort (i.e. unit price of staff). Higher productivity makes higher cost-effectiveness. Therefore, the answer of RQ1 is "The user should give weight to productivity of the developer more than unit price of staff." Maxwell et al. [11] also pointed out that the differences of productivity are large among developers. Similarly, when the developer outsources software development to subcontractors, it should care about productivity of the subcontractors more than unit price of staff.
- The relationship between productivity and unit price of effort was weak. That is, unit price of effort is not expensive on high productivity developers.
- The relationship between productivity and the price was moderately strong. This may because the relationship was affected by strength of the relationship between productivity and unit price of size (and the relationship between the price and unit price of size).
- Actual FP weakly related to other variables such as Unit price of size. So, an additional answer to RQ1 is "There is not strong need for the user to pay attention to software size to enhance cost-effectiveness, at a maximum size of 5,500 FP (the maximum value of FP in the dataset)."

C. Candidate explanatory variables of the model

To select candidate explanatory variables of the price estimation model, we analyzed relationships between the ratio variables such as productivity and other variables explained in section 2. We assume the estimated number of screens, reports, and files are decided after design phase. So, (estimated) screen/FP, report/FP, and file/FP are used for the candidate explanatory variables. Note that actual duration, error of duration, error of FP, and error of effort are not the candidate explanatory variables. They were used for other analysis.

The correlation coefficients are shown in Table 2. In the table, italic face means the relationship was statistically significant at 0.10 level (We did not set significant level severely because the purpose of the analysis is to select candidate variables. The significance level of 0.1 is sometimes used [1][8][16] to avoid type I error). System architecture, EIF/FP, EI/FP, screen/FP, and report/FP related to the ratio variables. They may indirectly denote characteristics of custom software such as mission-critical system, and the characteristics may affect the price. For example, when developing software needs high reliability, it may needs higher unit price of size, because more testing is needed and it lowers productivity. Based on the analysis results, the answer of RQ2 is "System architecture, EIF/FP, EI/FP, screen/FP, and report/FP should be used as candidate variables of the model, in addition to FP."

Error of duration, error of FP, and error of effort did not relate to the ratio variables. Therefore, the analysis results are considered to be not affected by project failure such as cost overrun. In the dataset, error of duration, error of FP, and error of effort were small, as shown in Fig. 3. However, if they are large, it may affect the result.

V. PRICE ESTIMATION BASED ON FP AND EFFORT

To answer RQ3, we analyzed estimation error of the price when it was estimated simply by multiplying FP or effort by the unit price (Building the price estimation model using the candidate explanatory variables identified in section 4 is the future work). The price is estimated as follows:

$$\hat{z} = x_i \tilde{x} \quad (3)$$

$$\hat{z} = y_i \tilde{y} \quad (4)$$

TABLE II. THE CORRELATION COEFFICIENTS OF CANDIDATE EXPLANATORY VARIABLES AND THE RATIO VARIABLES

	Unit price of Effort	Unit price of FP	Productivity
User classification	-0.19	0.04	0.16
	(0.32)	(0.83)	(0.39)
Contract classification	0.23	0.24	0.24
	(0.28)	(0.25)	(0.25)
Estimated duration	-0.07	0.05	0.07
	(0.71)	(0.79)	(0.71)
Actual duration	-0.11	0.07	0.09
	(0.59)	(0.72)	(0.65)
Error of duration	-0.25	-0.12	-0.09
	(0.21)	(0.55)	(0.65)
Error of FP	-0.25	-0.31	-0.23
	(0.26)	(0.14)	(0.30)
Error of effort	-0.08	0.11	0.18
	(0.70)	(0.61)	(0.41)
System architecture	0.02	*-0.38*	*-0.47*
	(0.92)	(0.04)	(0.01)
Operating system of the server	-0.11	0.23	0.28
	(0.63)	(0.34)	(0.23)
ILF/FP	0.13	-0.18	-0.26
	(0.62)	(0.47)	(0.30)
EIF/FP	*-0.66*	-0.26	0.01
	(0.01)	(0.35)	(0.96)
EI/FP	*0.61*	0.41	0.20
	(0.02)	(0.13)	(0.47)
EO/FP	-0.12	-0.10	-0.10
	(0.67)	(0.71)	(0.7)
EQ/FP	-0.16	0.00	0.08
	(0.56)	(1.00)	(0.77)
Screen/FP	*0.34*	*0.35*	0.26
	(0.08)	(0.07)	(0.19)
Report/FP	0.07	*0.51*	*0.54*
	(0.73)	(0.01)	(0.00)
File/FP	0.09	0.29	0.29
	(0.67)	(0.14)	(0.14)

TABLE III. MEDIAN *BRE* ON THE PRICE ESTIMATION

	Median *BRE*	95% confidence interval (lower)	95% confidence interval (upper)
FP based estimation	86.6%	53.1%	249.0%
Effort based estimation	20.2%	8.4%	34.1%

In the equations, $\hat{z}$ is estimated price, x_i is actual effort of the target project, $\tilde{x}$ is the median of unit cost of effort, y_i is actual FP of the target project, and $\tilde{y}$ is the median of unit cost of FP. Each price was estimated based on leave-one-out cross validation (i.e. the median was calculated with leave-one-out cross validation). Note that we did not show the median, to avoid abusing the result.

To evaluate accuracy of the estimation, we used median of *BRE* (Balanced Relative Error) [13]. When x denotes actual price, and $\hat{x}$ denotes estimated price, *BRE* is calculated by the following equation:

$$BRE = \begin{cases} \dfrac{|x - \hat{x}|}{x}, & x - \hat{x} \geq 0 \\ \dfrac{|x - \hat{x}|}{\hat{x}}, & x - \hat{x} < 0 \end{cases} \quad (5)$$

Lower value of *BRE* indicates higher estimation accuracy. *MRE* (Magnitude of Relative Error) [4], the popular criterion to evaluate estimation model, has biases for evaluating under estimation [3]. Maximum *MRE* is 1 even if terrible underestimate is occurred (For instance, when actual price is 1,000,000 yen, and estimated price is 0 yen, *MRE* is 1). So instead of *MRE*, we adopted *BRE* whose evaluation is not biased [14].

Additionally, we performed interval estimation of median *BRE* by bootstrapping. Bootstrapping is one of the resampling methods [7], and it randomly extracts cases from the dataset. The number of extracted cases is the same as the dataset allowing some cases to be extracted more than once (that is, sampling with replacement). For example, given a fit dataset containing cases $\{M_1, M_2, M_3, M_4\}$, bootstrapping extracts a sample such as $\{M_1, M_1, M_2, M_3\}$ or $\{M_1, M_2, M_2, M_4\}$. Generally, the extraction is repeated 1000 times.

Table 3 shows median *BRE* of the price estimation and the 95% confidence interval. Based on the result, the answer of RQ3 is "When FP and unit price of FP are known, estimation error (*BRE*) will be about 87% (at least 53%, at most 249%). So, when FP and unit price of FP are used to estimate the price, the prediction accuracy is not sufficient to validate the price accurately. However, it may be applicable to identify extremely high or low price (i.e. validate price roughly).

When effort and unit price of effort are known, estimation error will be about 20% (at least 8%, at most 34%)." Effort estimation (e.g. [2], [17]) may be also applied for the user to judge the validity of the custom software price, because price estimation based on effort showed high accuracy.

Fig. 3 shows boxplots of the ratio variables. Each value was normalized by dividing by the median. In boxplots, the bold line in each box indicates the median value. Small circles indicate outliers, that is, values that are more than 1.5 times larger than the 25%-75% range from the top of the box edge. The reason of lower accuracy of FP based estimation is that variance of productivity of projects was larger than unit price of effort (see Fig. 3), and it made variance of unit price of FP larger.

The difference of productivity is considered to be not caused by effort (cost) overrun. Fig. 4 shows productivity based on estimated value and actual value. The productivity based on actual value was slightly smaller (better) than estimated value. The result suggests effort overrun seldom occurred. So, the difference of productivity was considered to be caused by the difference of the each developer's

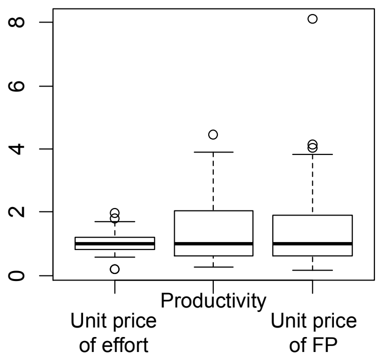

Figure 4. The variances of the ratio variables.

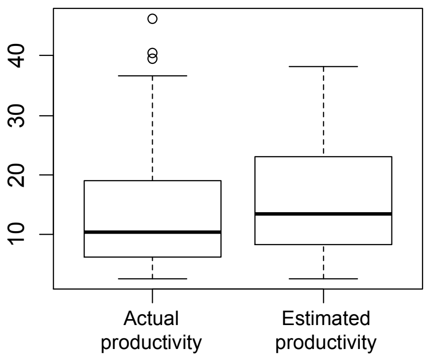

Figure 5. The difference of estimated and actual productivity.

performance, or the difference of difficulty of each custom software development.

VI. Related Work

To our knowledge, there is no research which analyzed variables relating to custom software price. So, there is little information for the user to judge the validity of the price. Some researches proposed price determination methods for package software [9][15]. However, the methods are used for the developer to gain maximum profit, and therefore they are not used for the user to judge the validity of the custom software price.

There is a research which analyzed variables relating to cost to sales ratio of custom embedded software [19]. However, cost to sales ratio does not relate to the price directly, and hence the analysis results are not used for the user to judge the validity of the price.

Analysis results in Section 2 suggest that ratio of staff of each rank such as project manager and programmer is not necessary to judge the validity of the price, because the most part of the price was explained by effort. Dong et al. [5] indicated the staffing pattern has no significant effect on productivity. The suggestion of our result is reinforced by the research.

VII. Conclusions

Our research goal is to give useful information for the user (end user company) to judge the validity of custom software price. To achieve the goal, we set three research questions, RQ1 to RQ3. We analyzed 31 custom software development projects collected from Japanese organizations, and answered to them as follows:

- Answer of RQ1: The user should give weight to productivity of the developer (software development company) more than unit price of staff.
- Answer of RQ2: System architecture, EIF/FP, EI/FP, screen/FP, and report/FP should be used as candidate variables of the price estimation model, in addition to FP.
- Answer of RQ3: When FP and unit price of FP are known, estimation error (*BRE*) will be about 87%. When effort and unit price of effort are known, estimation error will be about 20%.

Our future work is to build custom software price estimation model, and to analyze the accuracy.

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