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ESTIMATING THE VALUE OF JAVA AND C++ SKILLS

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ABSTRACT

C++ and Java are popular programming languages in university programs. Job postings show that Java and C++ are much in demand technical skills. In this paper, the human capital model was fitted to estimate the salary benefits of knowing C++ and Java. The analysis is based on survey data for 22,488 full-time information systems professionals. Based on the results for this model, we conclude that knowledge of Java produces a much greater salary increase than does C++. Of course, knowledge of both languages is particularly desirable because, as expected, knowledge of both languages results in the largest salary.

KEYWORDS: Java, C++, productivity, human capital model

I. INTRODUCTION

The Java programming language has received considerable attention during its relatively short existence. This attention may be attributed to a number of different factors. The launch of Java in 1995 involved a never-before-seen level of publicity for a programming language. In the mid-1990s, the popularity of the Internet increased, resulting in considerable interest surrounding Java applets.

McCauley and Manaris [1999] regularly survey accredited Computer Science programs. Before the release of Java, C++ was fast becoming the most popular language taught in Computer Science programs. In the 1995-1996 academic year, 36% still used Pascal as the first language taught in their programs but 32% of accredited Computer Science programs used C++ as the first language taught in their programs. Java first appeared in significant numbers in the 1997-1998 academic year with 9% of the accredited Computer Science programs using it as the first language taught. In the same 1997-1998 academic year, C++ usage rose to 47% while Pascal dropped to 6%. By the 1999-2000 academic year, Java increased to 22%, C++ increased to 54%, while Pascal dropped to 2%. From the McCauley and Manaris' [1999] study, it is clear that C++ and Java are very popular programming languages in university programs.

Examining the job postings on dice.com, a large on-line placement company for information systems professionals, showed that Java and C++ are much in demand technical skills. Of the 147,875 job postings on March 14, 2002, 14,920 (10.1%) mentioned Java and 18,927 (12.8%) mentioned C++. Other popular technical skills were SQL -- mentioned 17,302 (11.7%) times and Oracle -- mentioned 14,190 (9.6%) times. The next 3 most popular programming languages were ASP -- mentioned 5,690 (3.8%) times, Visual Basic -- mentioned 4,556 (3.1%) times, and Perl -- mentioned 4,197 (2.8%).

In comparing Java to C++, Eckel [1998] states "what has impressed me the most as I have come to understand Java is what seems like an unflinching goal of reducing complexity *for the programmer*." Gosling and McGilton [1996] state that the designers of Java designed a language that

> "is *simple*, so it can be easily programmed by most developers;
>
> *familiar*, so that current developers can easily learn the Java programming language;
>
> *object oriented*, to take advantage of modern software development methodologies and to fit into distributed client-server applications;
>
> *multithreaded*, for high performance in applications that need to perform multiple concurrent activities, such as multimedia; and
>
> *interpreted*, for maximum portability and dynamic capabilities".

Campione et al. [2000] describe Java in even more flattering terms going so far as to include a section in their book entitled "How Will Java Technology Change My Life?" They do, however, add the disclaimer

"*We can't promise you fame, fortune, or even a job if you learn the Java programming language. Still, it is likely to make your programs better and requires less effort than other languages*."

They praise Java in many areas:

1. Java is easy to learn,
2. Java requires less code (Java programs can be 4 times smaller than similar C++ programs),
3. Java encourages better coding practices,
4. Java programs are more quickly developed,
5. Java avoids platform dependencies,
6. Java provides "write once, run anywhere" capabilities, and
7. Java allows software to be distributed more easily.

Since Campione et al. [2000] claim that Java programmers are more productive than C++ programmers, we should expect that Java programmers should be paid more than their C++ programming counterparts, reflecting their greater productivity. This hypothesis assumes that wages are determined based on the value of a worker's marginal productivity. On the other hand, one may argue that Java programmers are paid more because of a strong market demand for cross-platform and web-based development. In either case, quantifying the current salaries of information systems professionals who know either Java or C++ should provide interesting results.

We use the human capital model to assess the current salaries of information systems professionals who know either Java or C++, or both languages or neither language. While the human capital model fitted in our study quantifies the salary differences for the different programming skill sets, the human capital model also controls for the effects of different amounts of technical experience and different levels of education (highest attained degree) that information systems professionals possess.

In the next section, the relevant theory from economics, human capital theory, is reviewed. Section III discusses the nature of our survey and presents summary statistics. Then, in Section IV, we fit the human capital model to our survey data set. The paper ends with a discussion of the limitations of our results and conclusions of our analysis.

II. HUMAN CAPITAL THEORY

The dominant economic theory of wage determination is human capital theory [Berndt, 1964]. Its roots date as far back as the 18th century writings of Adam Smith [1937] on equalizing or compensating for differences in wages paid to workers based on amenities and risks in the workplace.

Schultz [1960, 1961] popularized the idea of "human capital" -- the idea of treating educational spending as an investment. The human capital implications of education are a well-known and straightforward extension of Smith's idea of equalizing differences [Berndt 1991]. Educated workers are (hopefully) more productive than their less educated counterparts and thus are more likely to command higher wages. This theory also provides an economic explanation as to why a person will forego earnings and incur additional expenses to undertake an education since their efforts should result in substantially more compensation in the long run. In addition to formal education, on-the-job training is also important in the accumulation of one's human capital because many job skills are acquired through training sessions, apprenticeships, and similar efforts ([Becker 1961, 1964] and [Mincer 1957, 1962, 1974]).

For the most part, the econometric literature on wage determination is based on regression models of the following form: the natural logarithm of earnings is a function of a measure of schooling, a measure of experience, possibly other factors, and a random disturbance term. This model is based on Roy's [1950] research in which he related earnings distributions to the distributions of the underlying abilities (such as intelligence and physical strength).

Later work by Mincer [1974] showed the regression equation for wages is linear in education but quadratic in experience. That is:

$$\log Y_i = \log Y_0 + \beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + u_i \quad (1)$$

where Y_i is the wages for the i-th worker;
- Y_0 is the intercept term in the regression model which determines the base rate without education or experience;
- β_1 is the rate of return for education;
- S_i is the measure of educational attainment (in years) for the i-th worker which is simply the highest grade attended[1],
- X_i is the years of experience for the i-th worker;
- β_2 and β_3 are coefficients that assess the rate of return on experience; and
- u_i is the random disturbance associated with the i-th worker.

[1] For example, 16 years indicates a bachelor's degree;

Based on human capital theory, the wages function is concave in experience because as experience increases, earnings cannot increase indefinitely. That is, there is a maximum wage that can be reached. Therefore, estimates of β_2 should be positive while estimates of β_3 should be negative.

In addition to education and experience considered in human capital theory, technological change and an individual's skill set may also be considered. Krueger [1993], Dunne and Schmitz [1995], and Doms, Dunne, and Troske [1997] found a positive relationship between workers' wages and their use of various new technologies. When considering the presence of an additional specific skill, Equation 1 can be modified by adding an indicator or dummy variable that indicates whether the individual possesses a specific skill (or skill set) or not. To interpret the human capital model results better, we added 3 indicator variables (instead of just 2 indicator variables):

1. C_i which indicates whether the individual knows C++ only (and not Java),
2. J_i which indicates whether the individual knows Java only (and not C++), and
3. B_i which indicates whether the individual knows both C++ and Java. Note that if an individual possesses neither C++ nor Java skills, all 3 indicator variables equal 0.

Adding the indicator variables, Equation 1 becomes:

$$\log Y_i = \log Y_0 + \beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + \beta_4 C_i + \beta_5 J_i + \beta_6 B_i + u_i \qquad (2)$$

III. SURVEY DETAILS AND SUMMARY STATISTICS

The results presented here are based on a voluntary web-based survey on salary and skills of IT workers that was conducted by dice.com, an on-line placement company. To complete this survey, an individual was not required to use the job or resume posting services of dice.com. This survey can be found at the company's web site at http://www.dice.com. From June 7, 2000 to April 13, 2001, 22,488 full-time USA information systems workers correctly completed the survey on-line. This data set was used in our analysis.

Table 1 characterizes the respondents by their (technical) experience level (6 categories) and skills. Overall, 23.9% of the respondents were skilled in C++, Java, or both C++ and Java. Over the different experience levels, the number knowing either C++ or Java or both languages ranged from 21.7% (at the lowest experience level) to 25.0% (at experience level 4 – 6 to 10 years experience). Overall, 14.7% (7.2% C++ only) of the respondents were skilled in C++, 16.7% (9.2% Java only) in Java, and 7.5% in both languages.

Table 2 shows that the respondents who know neither language made, on average, only $57,989 while the respondents who know both languages made, on average, $74,034. Comparing the average salaries for knowledge of Java only versus knowledge of C++ only, Java only is slightly higher ($67,524 versus $65,155) than C++ only. Examining each of the 4 columns in Table 2 (C++ Only, Java Only, Both, and Neither), shows a clearly increasing pattern for average salary as experience increases.

Table 1. Experience and Skill: Percentages

Experience Level	Experience (years)	Number of Respondents	C++ Only	Java Only	Both	Neither
1	<1	2,338 (10.4%)	151 (6.5%) (9.3%)	197 (8.4%) (9.5%)	159 (6.8%) (9.4%)	1,831 (78.3%) (10.7%)
2	1 or 2	3,532 (15.7%)	236 (6.7%) (14.6%)	369 (10.4%) (17.8%)	235 (6.7%) (13.9%)	2,692 (76.2%) (15.7%)
3	3 to 5	7,040 (31.3%)	498 (7.1%) (30.8%)	695 (9.9%) (33.6%)	546 (7.8%) (32.2%)	5,301 (75.3%) (31.0%)
4	6 to 10	4,474 (19.9%)	316 (7.1%) (19.5%)	426 (9.5%) (20.6%)	377 (8.4%) (22.3%)	3,355 (75.0%) (19.6%)
5	11 to 14	1,938 (8.6%)	168 (8.7%) (10.4%)	144 (7.4%) (7.0%)	160 (8.3%) (9.4%)	1,466 (75.6%) (8.6%)
6	15 or more	3,166 (14.1%)	249 (7.9%) (15.4%)	240 (7.6%) (11.6%)	217 (6.9%) (12.8%)	2,460 (77.7%) (14.4%)
Overall		22,488	1,618 (7.2%)	2,071 (9.2%)	1,694 (7.5%)	17,105 (76.1%)

Table 2. Experience and Skill: Average Salaries ($/year)

Experience Level	Experience (in years)	C++ Only	Java Only	Both	Neither
1	<1	42,079	44,812	50,484	38,036
2	1 or 2	46,394	52,046	53,766	43,077
3	3 to 5	59,697	64,432	67,586	54,698
4	6 to 10	71,883	77,498	80,886	65,499
5	11 to 14	82,345	86,375	94,675	72,941
6	15 or more	87,707	89,875	102,341	77,098
Average Salary	60,591	65,155	67,524	74,034	57,989

In Table 3, the respondents were categorized by their highest educational level and skills. Education does seem to matter when knowledge of C++ or Java is considered. 27.5% of College grads know at least one of these languages, 39.2% of those possessing a Master's Degree know at least one of these languages, and 42.5% of those possessing a Doctoral Degree know at least one of these languages. These values are in sharp contrast to the overall result that only 23.9% of all respondents know at least one of these languages.

Table 3. Education and Skill: Percentages

Education Level	Number of Respondents	C++ Only	Java Only	Both	Neither
High School	1,407 (6.3%)	59 (4.2%) (3.6%)	86 (6.1%) (4.2%)	55 (3.9%) (3.2%)	1,207 (85.8%) (7.1%)
Military	405 (1.8%)	11 (2.7%) (0.7%)	26 (6.4%) (1.3%)	10 (2.5%) (0.6%)	358 (88.4%) (2.1%)
Vocation/Tech School	1,807 (8.0%)	78 (4.3%) (4.8%)	91 (5.0%) (4.4%)	41 (2.3%) (2.4%)	1,597 (88.4%) (9.3%)
Some College	5,837 (26.0%)	296 (5.1%) (18.3%)	369 (6.3%) (17.8%)	222 (3.8%) (13.1%)	4,950 (84.8%) (28.9%)
College Grad	9,079 (40.4%)	763 (8.4%) (47.2%)	992 (10.9%) (47.9%)	746 (8.2%) (44.0%)	6,578 (72.5%) (38.5%)
Master's Degree	3,355 (14.9%)	344 (10.3%) (21.3%)	439 (13.1%) (21.2%)	532 (15.9%) (31.4%)	2,040 (60.8%) (11.9%)
Doctoral Degree	351 (1.6%)	49 (14.0%) (3.0%)	44 (12.5%) (2.1%)	56 (16.0%) (3.3%)	202 (57.5%) (1.2%)
Professional Degree (MD, JD)	247 (1.1%)	18 (7.3%) (1.1%)	24 (9.7%) (1.2%)	32 (13.0%) (1.9%)	173 (70.0%) (1.0%)
Overall	22,488	1,618 (7.2%)	2,071 (9.2%)	1,694 (7.5%)	17,105 (76.1%)

In Table 4, average salaries were computed for highest attained educational level and skills. Education definitely seems to matter. For example, in terms of the average salary for knowledge of C++ only:

- College graduates made $65,210/year,
- Master's Degree holders made $76,369/year,
- Doctoral Degree holders made $80,122/year.

These values are in contrast to $65,155 for an average annual salary for all those who know of C++ only. Similar result were found for Java only and for both Java and C++.

The results in Table 2 and Table 4 definitely suggest that experience and education are two of the major factors that determine salary. For each of the different skills, annual salary increases monotonically with experience level. In terms of education, the same pattern emerges; possessing a college degree appears to increase salary. Hence, this data indicates that the human capital model would be an appropriate model.

Table 4. Education and Skill: Average Salaries ($/year)

Education Level	C++ Only	Java Only	Both	Neither
High School	49,254	51,360	69,945	47,636
Military	61,273	57,731	74,100	49,835
Vocation/Tech School	45,756	53,143	51,049	45,972
Some College	57,061	57,883	63,860	52,408
College Graduate	65,210	69,717	72,680	62,239
Master's Degree	76,369	75,927	79,241	72,722
Doctoral Degree	80,122	79,318	92,821	71,851
Professional Degree (MD, JD)	79,389	72,542	93,219	66,225
Overall	65,155	67,524	74,034	57,989

IV. MODEL RESULTS

Mincer [1974] showed that the regression equation for wages is linear in education but quadratic in experience, as given in Equation 1. Berndt [1991] suggested that rather than using annual salaries, the hourly salary rate should be employed. Since the respondents also indicated the average number of hours worked per week, we fitted the human capital model by taking the annual salary and dividing it by the estimated hours worked per year. The estimated hours worked per year is the number of weeks per year (365 / 7) times the average hours worked per week. Since the respondents indicated a technical experience level rather experience in years, the experience level was scaled as follows:

Scale Value	Experience in years
1	<1
1.5	1-2
3.5	3-5
7.5	6-10
12.5	11-14
17.5	>14

The highest education level attained by each respondent was scaled into education years as follows:

Scale Value	Education Level
12	High School
14	Military
14	Tech/Vocational School
14	Some College
16	College Graduate
18	Masters Degree
20	Doctorate
20	Professional Degree (JD or MD)

In this section, we present results for the human capital model. Note that the wage units are dollars per hour. In the results presented, the coefficients will be referred as the Base (intercept term), Education (β_1), Experience (β_2), Experience_Squared (β_3), C++ only (β_4), Java only (β_5), and Both (β_6).

Table 5 presents the overall results for the human capital model. The model and each coefficient are highly significant. As expected by the human capital model, the coefficient of Experience is positive while the coefficient of Experience_Squared is negative. Knowledge of both C++ and Java pays a greater dividend (0.145) than knowledge of either one of these languages (0.036 and 0.123). Knowledge of Java pays a greater dividend (0.123) than knowledge of C++ (0.036).

Table 5. Human Capital Model Results

Coefficient or Statistic of Interest	Value
Base	1.752505 *
Education	0.070897 *
Experience	0.081276 *
Experience_Squared	-0.002776 *
C++ Only	0.035819 *
Java Only	0.123038 *
Both	0.144686 *
Adjusted R-Square	0.2187
p-value of Model	0.0001

* coefficient significantly different from 0 at .01 level

To interpret the results better, we transform equation (2) by applying the exponential function to both sides. This transformation yields:

$$Y_i = Y_0 e^{\beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + \beta_4 C_i + \beta_5 J_i + \beta_6 B_i + u_i} \quad (3)$$

Substituting the fitted values into this equation shows that, compared to an individual's salary with neither language skill, knowledge of C++ only results in a salary increase of 3.6% (since $e^{0.035819} = 1.036$), knowledge of Java only results in a salary increase of 13.1% and knowledge of both C++ and Java results in a salary increase of 15.6%.

V. LIMITATIONS AND CONCERNS

In evaluating the human capital model, some reservations must be expressed concerning its application [Berndt 1991]:

1. "wage determination may reveal only a portion of the total compensation differentials among workers",
2. "it is often difficult to obtain accurate data on hours worked by salaried people", and
3. "the practicing econometrician in labor economics is typically forced to make use of data that are considerably less than ideal"

Berndt, however, does add that "in spite of these serious measurements much has been learned concerning the determinants of wages").

Other concerns can be raised by the representation of the respondents of this survey.

First, the survey sample was not random since the respondents were totally self-selected.

Second, the survey was on-line which may introduce a bias towards younger workers.

Third, the on-line respondents may be biased towards Java and web-based applications because Java is used much more in web-based applications (with applets, servlets, and JSP). Further, the time period of the survey may have tilted the results towards Java.

Fourth, the survey was placed on an on-line placement company's web site which may indicate that the survey respondents were more actively seeking new employment compared to typical IT workers.

Fifth, only salary data for USA workers were included in our analyzed data set.

Sixth, programming "skill" is much more than just "knowing" the language. The survey does not directly differentiate between ordinary and exceptional programmers (one might argue, however, that knowing both Java and C++ indicates a higher programming skill level). Clearly, exceptionally skilled programmers should command greater salaries than their less skilled peers.

SIDEBAR 1

SENSITIVITY ANALYSIS

In response to one of the reviewers who argued that a doctorate requires more than two years beyond a Master's degree today, we ran a sensitivity analysis on our model in which we scaled the doctorate as requiring 22 years rather than 20 for the doctorate. The results obtained (Table 6) are quite similar to the results in Table 5. For example, the difference for knowing both languages with 22 years for the doctorate is equal to 16.4% compared to 15.6% with 20 years for the doctorate.

Table6. Recalculation of Table 5 with 22 years for the Doctorate

Coefficient or Statistic of Interest	Value
Base	1.891 *
Education	0.061 *
Experience	0.082 *
Experience_Squared	-0.0028 *
C++ Only	0.040 *
Java Only	0.128 *
Both	0.152 *
Adjusted R-Square	0.213
p-value of Model	0.0001

* coefficient significantly different from 0 at .01

VI. CONCLUDING REMARKS

Despite some reservations and concerns, we feel that our human capital model provides a good indication of the value of Java and C++ programming skills. We used the human capital model to assess the current salaries of information systems professionals who know either Java or C++ or both languages or neither language. The human capital model controls for the different amounts of technical experience and the different levels of education (highest attained degree) which information systems professionals possess.

Based on the results for this model, knowledge of Java produces a much greater salary increase than C++. If wages are determined based on the value of a worker's marginal productivity, our results provide support for the claim by Campione et al. [2000] that Java programmers are more productive than C++ programmers. On the other hand, one may argue that our results support a greater market demand for Java programmers (particularly, cross-platform and Web-based development).

Knowledge of both languages is particularly desirable to the IT worker as knowledge of both languages, as expected, produced the greatest salary. On the other hand, why would an organization be willing to pay extra for knowledge for both Java and C++? In some cases, the organization develops and supports applications using both languages so there is a clear need for knowledge of both languages. In other cases, the organization may only use one language. For these cases, we postulate that there is a strong positive relationship between knowing both languages and programming skill level which explains the salary premium. At first glance, Java is very similar to C++ in syntax. On the other hand, "if you have programmed in either C or C++, the transition to Java can be troublesome" [Savitch 2001] as C++ and Java are quite different in language design. In fact, Savitch [2001] devotes an entire Appendix to the major differences between C++ and Java. Therefore, making the transition to learn the other language is not that simple. Therefore, we conclude that, in general, stronger programmers know both languages.

In terms of future studies, it will be interesting to track the job demand and average salaries of C# programmers (as some consider C# the "illegitimate child" of Java and C++). A number of other interesting questions could be addressed by a study like this. Will C# programmers get a major salary premium for knowing this new language? Will new programmers gravitate toward C# instead of Java and C++?

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