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THE HUMAN CAPITAL VALUE OF OOP

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ABSTRACT

If object-oriented programmers are more productive than other programmers, they should be paid more, assuming that wages are determined based on the value of a worker's marginal productivity. The human capital model is used to assess the current salary premiums of programmers who know object-oriented programming (OOP). While the human capital model employed quantifies this premium, it also controls for the effects of different amounts of technical experience and different levels of education (highest attained degree) that the programmers possess. Using two samples, the incremental value of OOP skills is shown to be about the same over the two different time periods (2000/2001 and 2003).

Keywords: OOP, programmers, human capital model

I. INTRODUCTION

Most of the early discussions about object-oriented (OO) development emphasized potential benefits. Martin [1992] categorized OO as being more natural for analysts and simpler for designers and programmers than traditional approaches. Coad and Yourdon [1990] focused on the simple and natural concepts of OO and the inherent reduction of complexity produced by OO. Rather than arguing that OO is more natural or simple, Booch, Rumbaugh, and Jacobson [1999] emphasize that the benefits of OO come from its building block approach to system development. Information systems developed with traditional approaches are notoriously error-prone, expensive, and inflexible. By employing a building block approach to system development, the potential to reduce errors, reduce costs, and increase flexibility is substantial [Booch, Rumbaugh, and Jacobson, 1999].

Perhaps the most important benefit of the OO building block approach to system development for the developer is that of reuse. Although traditional developers long argued for reusing code modules in procedural languages such as COBOL, reuse in object-oriented programming (OOP) offers substantial improvement. Each object in a system is relatively small, self-contained, and

manageable. Once an object is defined, implemented, and tested, it can be reused in other systems. Reuse can not only increase productivity, but it also improves software quality because the reused objects are proven products. Since objects are self-contained units that can be changed or replaced without interfering with the rest of the system, the system can be modified or enhanced easily, by changing some types of objects or by adding new types of objects. Hence, OOP allows reuse in a more comprehensive and practical way [Martin, 1992].

Reuse is even more powerful when existing classes are extended into new subclasses through inheritance. In addition, reuse of classes developed specifically for company systems (problem domain classes), such as accounting, inventory, CRM, and planning, is possible if developers begin to catalog classes they developed. Reuse of problem domain classes from system to system in the same company increases efficiency and facilitates a higher degree of integration among company systems. Further, reuse can be done at an industry level by using collections of classes, called frameworks. Moreover, the benefits of reusability can be applied at a more abstract level. Design patterns are now published that programmers can draw on to find solutions to common programming situations, saving time and leading to more robust solutions [Gamma, et al., 1995].

Most experienced developers now view OO development as superior to traditional development approaches [Johnson, 2000]. If OO programmers are more productive than other programmers, we should expect that they would be paid more than their counterparts, reflecting their greater productivity. This hypothesis assumes that wages are determined by the value of a worker's marginal productivity. On the other hand, one may argue that OO programmers are paid more because of a strong market demand for OOP skills. In either case, quantifying the current salaries of programmers who know OOP should provide interesting results.

We use the human capital model [Berndt, 1991] to assess the current salary premiums of programmers who know OOP. While the human capital model fitted in our study quantifies this premium, it also controls for the effects of different amounts of technical experience and different levels of education (highest attained degree) that the programmers possess. Rather than using only one data sample, we employ two samples to determine whether the value of OOP is consistent over two different time periods (2000/2001 and 2003).

In Section II, the relevant human capital theory from economics is reviewed, and the details of the basic human capital regression model are described. The nature of our survey is discussed briefly (Section III) and summary statistics are presented (Section IV) for the two samples. Then, we fit the human capital model to our survey data sets (Section V). The paper concludes with our assessment of the current and future value of OOP.

II. HUMAN CAPITAL

The dominant economic theory of wage determination is human capital theory [Berndt, 1991]. Its roots date as far back as the 18th century writings of Adam Smith [1937, originally published in 1776] on equalizing or compensating for differences in wages paid to workers based on amenities and risks in the workplace. The human capital implications of education are a well-known and straightforward extension of Smith's idea of equalizing differences [Berndt, 1991]. Schultz [1960, 1961] popularized the idea of "human capital" -- the idea of treating educational spending as an investment. 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 a person's human capital because many job skills are acquired through training sessions, apprenticeships, and similar efforts [Becker 1962, 1964; Mincer 1958, 1962, 1974].

To show how OOP improves the earnings of software developers, we build on the well-established human capital model to assess the value of OOP. 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 education, a measure of experience, possibly other factors, and a random disturbance term. That is,

$$\text{Log}_e(\text{earnings}) = f(\text{education, experience, other factors}) + \text{error term}, \quad (1)$$

This relation 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). In using these regression models, Berndt [1991] suggested that rather than using annual salaries, the hourly salary rate should be employed. Mincer [1974] showed the regression equation for wages is linear in education but quadratic in experience. That is:

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

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. For example, 16 years indicates a bachelor's degree;

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.

Based on human capital theory, the wages function is concave in experience because as experience increases, earnings cannot increase indefinitely. That is, only a maximum wage 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, Krueger [1993], Dunne and Schmitz [1995], and Doms, Dunne and Troske [1997] found a positive relationship between workers' wages and their skills in the 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 has the specific skill or not. To assess the value of OOP skills an addition term is added to Equation 1 where O_i equals 1 if the software developer indicates knowledge of OOP and 0 otherwise.

$$\log Y_i = \log Y_0 + \beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + b_4 O_i + u_i \quad (3)$$

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

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

Berndt does add that "in spite of these serious measurement problems much has been learned concerning the determinants of wages".

IV. SURVEY DETAILS AND SUMMARY STATISTICS

The results presented here are based on a voluntary web-based survey on salary and skills of Information Technology (IT) workers that was conducted by Dice Incorporated, an on-line placement company. Two data sets were acquired. The first data set contains survey responses from June 7, 2000 to April 13, 2001. The second data set presents survey responses from January 1, 2003 to September 1, 2003. This survey can be found at the company's web site at <http://www.dice.com>.

In the on-line survey, a respondent could select from 38 different job titles. To identify programmers, we used 7 of these job titles -- Developer: Applications, Developer: Client/Server, Developer: Database, Developer: Systems, Mainframe Systems Programmer, Software Engineers, and Web Developer/Programmer. Programmers who indicated knowledge of C++, Java, Smalltalk, or OOP on the survey were credited with knowledge of OOP in our analysis. Any problematic data was removed from our sample using the rules listed in the Appendix. This procedure resulted in a sample of 5,547 programmers for the first survey period and 2,172 programmers for the second survey period. Two caveats can be raised regarding the representation of the respondents of this survey:

1. the survey sample was not random since the respondents were self-selecting and voluntary, and
2. because it was not possible to verify the respondents' data, a self-reporting bias may exist.

Since the respondents indicated a technical experience level in a range rather stating experience in years, the experience level was scaled as follows:

Score	No. of years	Score	No. of years
0.5	< 1 year	8.0	6-10
1.5	1-2 years	12.5	11-14
4.0	3-5 years	17.5	>15 years

The highest education level attained by each respondent was scaled into education years as follows: (1) 12 for High School, (2) 14 for Military, (3) 14 for Vocational/Tech School, (4) 14 for Some College, (5) 16 for College Grad, (6) 18 for Master's Degree, (7) 20 for Doctoral Degree, and (8) 20 for Professional Degree (MD, JD).

In Table 1, sample statistics are given for the two survey periods. The yearly salaries increased substantially from the Period 1 to the Period 2. The respondents in Period 2 also possess greater experience and education which may partially explain their greater salaries. In addition, a substantially greater proportion of respondents in Period 2 were OOP skilled, which may also help explain their greater salaries.

Table 1. Summary Statistics for Entire Population

Statistic	Period 1	Period 2	Difference (Period 2 – Period 1)
Sample Size	5,547	2,172	-3,375
Yearly Salary	64,807	72,984	8,177 ***
Experience	6.17	8.09	1.92 ***
Education	16.08	16.39	0.31 ***
Hours Worked (per week)	42.53	42.32	-0.21
Proportion with OOP Skill	52.0%	58.3%	6.3% ***

- * significant differences at .10 level
 ** significant differences at .05 level
 *** significant differences at .01 level

V. HUMAN CAPITAL MODEL RESULTS

Table 2 presents the overall results for the human capital model. Each model and each coefficient are highly significant. As expected by the human capital model, the experience coefficient is positive while the experience_squared coefficient is negative. The experience coefficient was larger for Period 2 while the education coefficient was greater in Period 1.

Table 2. Human Capital Model Results for Entire Population

Coefficient or Statistic of Interest	Period 1	Period 2
Intercept or Base	2.21488*	2.42584 *
Education	0.04660*	0.02898 *
Experience	0.09174 *	0.10956 *
Experience_Squared	-0.00348 *	-0.00383 *
Adjusted R-Square	0.1970	0.2554
p-value of Model	< 0.0001	< 0.0001

* coefficient significantly different from 0 at < 0.0001 level

Table 3 presents the overall results for the human capital model with OOP.

Table 3. Human Capital Model Results for OOP

Coefficient or Statistic of Interest	Period 1	Period 2
Intercept or Base	2.24279*	2.43123 *
Education	0.04245*	0.02572 *
Experience	0.09086*	0.10883 *
Experience_Squared	-0.00342*	-0.00378 *
OOP	0.07809*	0.08474 *
Adjusted R-Square	0.2049	0.2647
p-value of Model	< 0.0001	< 0.0001

* coefficient significantly different from 0 at < 0.0001 level

Again, the model and each coefficient are highly significant, the Experience coefficient is larger in Period 2, and the Education coefficient is larger in Period 1. To interpret the results better, we transform equation (2) by applying the exponential function to both sides. This transformation yields Equation 4:

$$Y_j = Y_o \exp(\beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + \beta_4 O_i + u_i) \tag{4}$$

Substituting the OOP coefficient value into this equation shows that knowledge of OOP results in a salary increase of 8.1% (since $e^{0.07809} = 1.081$) for Period 1 period and 8.8% (since $e^{0.084704} = 1.088$) for Period 2.

To provide additional evidence for the value of OOP, Table 4 presents the overall results for the human capital model with the COBOL skill replacing OOP. Again, the model and each coefficient are highly significant and the experience coefficient is larger in Period 2 while the education coefficient is larger in Period 2. Substituting the COBOL coefficient value into equation (3) shows that knowledge of COBOL results in an apparent salary reduction because $e^{-0.06547} = 0.937$ and $e^{0.07017} = 0.932$. One should, however, not conclude that learning COBOL reduces one's human capital. The nature of regression is the reason for these two results: since OO programmers make more than average, non-OO programmers must make less than average.

Table 4. Human Capital Model Results for COBOL

Coefficient or Statistic of Interest	Period 1	Period 2
Intercept or Base	2.22207*	2.44662 *
Education	0.04642*	0.02799 *
Experience	0.09166*	0.10928 *
Experience_Squared	-0.00343*	-0.00377 *
COBOL	-0.06547*	-0.07017 **
Adjusted R-Square	0.1990	0.2577
p-value of Model	< 0.0001	< 0.0001

* coefficient significantly different from 0 at ≤ 0.0001 level

** coefficient significantly different from 0 at 0.0059 level

In examining these three models, it is clear that the model coefficient structures changed significantly between the two periods. Performing a Chow [1960] test for each of these models confirms this change with a p-value < 0.0001 for the three models. To examine the changes between periods for the OOP model further, an additional regression was performed using dummy variables for changes in the coefficients [Maddala, 1992]. An additional set of regression coefficients were added that indicated the change in coefficient values from Period 1 to Period 2. These additional coefficients are the β coefficients given in Equation 5. To perform this regression, the data for the two periods were combined.

$$\log Y_j = \log Y_0 + \alpha_0 + \beta_1 S_i(1 + \alpha_1) + \beta_2 X_i(1 + \alpha_2) + \beta_3 X_i^2(1 + \alpha_3) + \beta_4 O_i(1 + \alpha_4) + u_i \quad (5)$$

The results of this regression model are given in Table 5. The results confirm that education, experience, and OOP skills significantly determine a programmer's salary. The value of OOP skills, however, did not change significantly between these two periods. Similarly, experience_squared did not change significantly between these two periods. On the other hand, the value of education dropped significantly from Period 1 to Period 2 while the value of experience increased significantly from Period 1 to Period 2. The model results also confirm that the salary of programmers increased significantly from Period 1 to Period 2 because the intercept increased significantly.

Table 5. Changes in Coefficients between Periods

Coefficient or Statistic of Interest	Value	P-Value
Intercept	2.24279	<.0001
Intercept Change	0.18844	0.0481
Education	0.04245	<.0001
Education Change	-0.01673	0.0034
Experience	0.09086	<.0001
Experience Change	0.01797	0.0160
Experience_Squared	-0.00342	<.0001
Experience_Squared Change	-0.00035566	0.3476
OOP	0.07809	<.0001
OOP Change	0.00665	0.7319
Adjusted R-Square	0.2338	
p-value of Model		< 0.0001

* coefficient significantly different from 0 at < 0.0001 level

VI. CONCLUDING REMARKS

The clear conclusion from our models is that, at this time, knowledge of OOP makes a major positive impact on a programmer’s earnings. Knowledge of OOP resulted in a salary premium of 8.1% for Period 1 period and 8.8% for Period 2. The additional increase of 0.7% of the salary premium from Period 1 to Period 2 should not, however, be interpreted as the value of OOP is increasing because this difference was not statistically significant.

CURRENT TRENDS

Job growth for IT workers accelerated during the 1990’s. But, in 2000 the demand for IT workers began to decline. The Information Technology Association of America [2003] reports (Table 6) that that the number of employed IT workers in the U.S. remained stable during the past four years. This result is very surprising considering the number of layoffs announced in the press. The creation of new job was offset by employee terminations, a situation that resulted in a decrease of available IT jobs. In essence, there has been no industry job growth for four years.

Table 6. IT Workforce

	Number of Employed IT Workers	Number of new jobs offerings	Number of new jobs offerings unfilled
2000	10,000,000	1,600,000	843,328
2001	10,400,000	900,000	425,000
2002	10,226,243	1,148,639	578,711
2003	10,312,650	493,431	No Data Available

Source: [ITAA, 2000, 2001, 2002, 2003a, 2003b]

Programmers constitute nearly 21% (or 2,144,377) of the 10,312,650 IT workers in the 2003 U.S. workforce [ITAA 2003b]. Future demand for programmers [U.S. Department of Labor, 2000b] is expected to be for those that possess strong OOP capabilities and technical specialization in areas such as client/server programming, multimedia technology, and graphic user interface (GUI). This demand should arise from the expansion of intranets, extranets, and internet applications. College graduates with knowledge and experience working with a variety of programming languages and tools, including C++ and other OO languages like Java, will have the best prospects.

FUTURE SCENARIOS

We conclude with a number of possible future scenarios that could affect the demand for OOP skills and the associated salary premium. We outline four such scenarios which in our opinion could have significant impacts on the salary premium of OO skills identified by this study.

Scenario 1: Easier and More Productive Development

Ongoing developments in tools, techniques, models, and methodologies will eventually make OO development easier, which could greatly increase the number of developers with OO skills. Some current developments in analysis and design methods such as the Unified Process (UP) [Jacobson, Booch, and Rumbaugh, 1999], agile modeling [Ambler, 2002], and eXtreme Programming (XP) [Beck, 2002] will help developers adapt better to OO. New tools, such as Rational XDE, will better integrate analysis and design models with program code to make the models more useful and natural. The acquisition of Rational Software by IBM may indicate that OO development is now truly “mainstream.” Software reuse will increase as companies improve the cataloging of problem domain classes, industry frameworks, and design patterns. These developments could also decrease the demand for workers with OO skills because OO developers may become more productive in the future.

Scenario 2: Increased Supply

Two current developments can increase supply of OO programmers significantly and reduce the premium for OO skills. First, realizing the benefits of OO skills, universities may produce graduates with OO skills at a much faster rate than people with those skills are retiring or leaving the programming profession or the increase in demand. Second, offshore outsourcing will increase the availability pool of OO programmers.

Since OO development can be viewed as a building block approach to system development, a specific programmer can focus on developing a specific block rather than the whole system. If the requirement for the specific block is well-defined, the programmer can be working on this block anywhere in the world. In 2003, Gartner Inc. predicted that between then and the end of 2004, 5% of current corporate IT jobs in the U.S, and 10% of the positions at U.S. IT vendors and technology services firms will be moved from the U.S. to other countries. Even more troubling, Gartner Inc. predicted that over 60% of the U.S. workers whose jobs are shifted to offshore operations will not be redeployed – that is, they will lose their jobs [Gartner, 2003]. On the other hand, it is doubtful that offshore programmers will take away a large portion of the U.S. programming jobs simply because the demand for programmers is considerable in Europe and Asia. Further, it is doubtful that development of systems where security is of paramount importance will be done offshore. However, with a larger potential supply of workers skilled in OO, the salary premium for OO skills is likely to be lessened or eliminated.

Scenario 3: Retirement of Baby Boomers

The third scenario suggests that a reasonable argument for acquiring COBOL skills could be made because IT organizations will face a rash of “baby boomer” retirements during 2005-2007. These retirements will cut across all skill areas from the highly technical to the managerial. Specifically, demand for COBOL, CICS, and mainframe skills will increase substantially as baby boomers retire [META, 2002]. Approximately 75% of all production transactions on mainframes use COBOL, 60% of all Web access resides on a mainframe, and over 95% of finance and insurance data is processed with COBOL [Arranga, 2002]. These COBOL applications will continue to be used until replaced or discarded. And, since many of these applications were just rejuvenated to address the Y2K issue, it is unlikely that the investment will be discarded in the immediate future. As a result, these systems will require skilled COBOL programmers to maintain them. Hence, COBOL programming skills (rather than OOP skills) may command salary premiums in the future. On the other hand, the projected rash of baby boomer retirements may lead organizations to replace their legacy systems with new systems built using OO techniques.

Scenario 4: The Next “Big Thing”

Programming languages evolved from machine languages to assembly languages to procedural languages to non-procedural languages to visual programming language to object-oriented programming languages. This historic pattern indicates that changes are inevitable. The next “big thing” might be aspect oriented programming, component development, frameworks, or some other new programming approach. When the next “big thing” takes off, the current premium commanded by OO skills will probably be lessened and programmers with this new in-demand skill will command salary premiums.

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EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers who have the ability to access the Web directly from their computer or are reading the paper on the Web, can gain direct access to these references. Readers are warned, however, that

1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
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APPENDIX I. DATA TREATMENT

We adopted the following rules in an attempt to make the self-selected dataset clean. By doing so, some legitimate observations, in addition to the obvious outliers, may have been removed. However, it is our belief that it is better to stay on the safe side.

Items	Exclusion Rules	Rationale
Age	Age 1 (18 under), 7 (60-64) and 8 (65 and over)	Lack of representation
Education	Education 1 and Education 10	Education 1 is default value and 10 is Other, which is unknown to us.
Job Title	35: Non-IT: Executive/ Corporate 36: Non-IT: Financial 37: Non-IT: Manufacturing / Operations	Our interest is limited to ITP.
Hours per Week	Category 1 (< 20 hours/week)	This is the default value and if not carefully enough respondents would have unintentionally selected it.
Country	Non-U.S.A countries	Our Intention is to focus on U.S.A.
Age * Exp	(Age 18-24) AND (Experience of 11 years or more)	It is unlikely for young people to acquire this many years of experience
Exp * Yearly Salary	(Technical experience is less than 1 year) AND (Yearly salary is greater than \$100K) (Technical experience is 1-2 years) AND (Yearly salary is greater than or equal to \$125K)	Unlikely

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