Empirical study of the effects of open source adoption on software development economics

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  - Population and sampling
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Open source software (OSS) is considered for commercial software development

- Importance of OSS increases
  - Use an existing software system as a base
  - Component adoption can happen at the level of fine granularity
    - Give a rich foundation to reusable software components
Lack in the empirical study of the effects of OSS adoption on development economics

- In this paper, the objectives empirically investigate the effects
  - OSS components reuse adoption
  - OSS adoption maturity level
  - OSS reuse experience of developers
  - Importance of OSS ‘select criteria’
  - Size of the organization
Overall approach

Population and sampling methods
- Getting an approximation of the truth for the formulation of the model, hypotheses, and survey questionnaires

Hypothesis
- Getting a hypothesis between OSS adoption variables and software development economics based on interviews and literature reviews

OSS adoption conceptual model
- Getting the conceptual model based on the hypothesis

Analysis of the results
- Getting the insights on relationships between OSS adoption variance and software development economics
Population and sampling methods (1/3)

- **Initiating the information of OSS adoption**

  - Convenience and judgment sampling
    - 6 organizations
    - Initial exploratory study from interviews

  - Random sampling
    - 120 organizations
    - Questionnaires through e-mail to the PM, QM who are involved in OSS adoption projects

  - Willing sampling
    - 60 (among 75) organizations

- Getting an initial inexpensive approximation of the truth
- Used in the formulation of research model, hypotheses, and survey questionnaire
### Define the measures from the interviews

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of OSS reuse</td>
<td>How high was the usage level in several development activities of this project against other projects?</td>
</tr>
<tr>
<td>Maturity level</td>
<td>What are the maturity levels for reusing OSS components?</td>
</tr>
<tr>
<td>Experience and skill</td>
<td>What is the required level of OSS reuse experience and skill?</td>
</tr>
<tr>
<td>Select criteria</td>
<td>How important are the OSS components selection criteria for each of the software development activities?</td>
</tr>
<tr>
<td>Success measures</td>
<td>How the outcome of the project meets performance goals (budget, productivity, and quality goals)?</td>
</tr>
<tr>
<td>Size of organizations</td>
<td># of employees, # of developers, annual revenues</td>
</tr>
</tbody>
</table>

Likert scale is used
Likert scale is used in questionnaires

- Form of psychometric response scale
  - Bipolar scaling method used for measuring either positive or negative response to a statement

<table>
<thead>
<tr>
<th>Rating level</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not sure</td>
<td>0</td>
</tr>
<tr>
<td>Not at all</td>
<td>1</td>
</tr>
<tr>
<td>Rarely</td>
<td>2</td>
</tr>
<tr>
<td>Moderately</td>
<td>3</td>
</tr>
<tr>
<td>Moderately high</td>
<td>4</td>
</tr>
<tr>
<td>High</td>
<td>5</td>
</tr>
<tr>
<td>Very high</td>
<td>6</td>
</tr>
</tbody>
</table>
Hypothesis

- Make the hypothesis based on the literature reviews and interviews

OSS adoption variables
- Degree of adoption
- Reuse maturity level
- Reuse experience and skill
- Selection criteria for OSS reuse

Control variable
- Size of organizations

Software development economics
- Cost of SW development
- Productivity of SW development
- Quality of SW development
Hypothesis for each model -> each variable has the **positive** effects on
(a) Budget
(b) Productivity
(c) Quality

Company size has the effects on
(a) OSS adoption variables
(b) Software development economics
### Mean and SD for each variable

*Unit: Likert scale*

<table>
<thead>
<tr>
<th>Measures</th>
<th>Mean</th>
<th>Likert scale</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of adoption</td>
<td>3.6902</td>
<td>Moderately high</td>
<td>1.1654</td>
</tr>
<tr>
<td>Motivation level</td>
<td>2.8200</td>
<td>Coordinated</td>
<td>0.9920</td>
</tr>
<tr>
<td>Experience and skill</td>
<td>2.7083</td>
<td>Advanced</td>
<td>0.87596</td>
</tr>
<tr>
<td>Select criteria</td>
<td>2.8</td>
<td>Important</td>
<td>0.84973</td>
</tr>
<tr>
<td>Budget</td>
<td>2.57</td>
<td>Above target</td>
<td>0.9630</td>
</tr>
<tr>
<td>Productivity</td>
<td>2.8</td>
<td>Above target</td>
<td>0.7080</td>
</tr>
<tr>
<td>Quality</td>
<td>2.77</td>
<td>Above target</td>
<td>0.8900</td>
</tr>
<tr>
<td>Company Size</td>
<td>1.5</td>
<td>Medium</td>
<td>0.5040</td>
</tr>
</tbody>
</table>
Normality test for each variable

<table>
<thead>
<tr>
<th>Measures</th>
<th>Skewness statistics</th>
<th>Kurtosis statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of adoption</td>
<td>0.608</td>
<td>-0.502</td>
</tr>
<tr>
<td>Motivation level</td>
<td>0.318</td>
<td>-0.411</td>
</tr>
<tr>
<td>Experience and skill</td>
<td>0.124</td>
<td>-0.758</td>
</tr>
<tr>
<td>Select criteria</td>
<td>0.728</td>
<td>-0.634</td>
</tr>
<tr>
<td>Budget</td>
<td>-0.666</td>
<td>-0.731</td>
</tr>
<tr>
<td>Productivity</td>
<td>-0.876</td>
<td>1.209</td>
</tr>
<tr>
<td>Quality</td>
<td>-0.411</td>
<td>-0.433</td>
</tr>
<tr>
<td>Company Size</td>
<td>0.000</td>
<td>-2.070</td>
</tr>
</tbody>
</table>

All the variables are normally distributed.

Pearson product-moment correlation coefficient is used for analyzing the relationships between the variables.

Normalized if value → 0
Not normalized if |value| is larger
Correlation coefficient and validity of them

<table>
<thead>
<tr>
<th>Measures</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Degree of adoption</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Maturity level</td>
<td>0.737</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Experience and skill</td>
<td>0.595</td>
<td>0.633</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Select criteria</td>
<td>0.845</td>
<td>0.646</td>
<td>0.490</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Budget</td>
<td>0.241</td>
<td>0.128</td>
<td>0.169</td>
<td>0.431</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Productivity</td>
<td>0.193</td>
<td>0.349</td>
<td>0.068</td>
<td>0.115</td>
<td>0.119</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Quality</td>
<td>0.573</td>
<td>0.431</td>
<td>0.292</td>
<td>0.565</td>
<td>0.473</td>
<td>0.140</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8 Company Size</td>
<td>0.004</td>
<td>-0.243</td>
<td>-0.086</td>
<td>-0.119</td>
<td>-0.105</td>
<td>-0.475</td>
<td>-0.113</td>
<td>1</td>
</tr>
<tr>
<td>Variance extracted</td>
<td>1.358</td>
<td>0.983</td>
<td>0.767</td>
<td>0.722</td>
<td>0.928</td>
<td>0.502</td>
<td>0.792</td>
<td>0.254</td>
</tr>
</tbody>
</table>

Threshold of $r$ between 0.243 and 0.273

Quality is more powerful benefits of OSS than budget and productivity if it implements OSS adoption in a systematic way.
Analysis for H1 model (degree of OSS adoption)

<table>
<thead>
<tr>
<th>Development activities</th>
<th>Budget</th>
<th>Productivity</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software test</td>
<td>0.394</td>
<td>0.188</td>
<td>0.584</td>
</tr>
<tr>
<td>Core functionality</td>
<td>0.145</td>
<td>0.393</td>
<td>0.197</td>
</tr>
<tr>
<td>Platform</td>
<td>0.281</td>
<td>0.276</td>
<td>0.579</td>
</tr>
<tr>
<td>Design pattern</td>
<td>-0.131</td>
<td>-0.326</td>
<td>0.167</td>
</tr>
<tr>
<td>Tools</td>
<td>0.150</td>
<td>0.167</td>
<td>0.405</td>
</tr>
<tr>
<td>Product architecture</td>
<td>0.095</td>
<td>0.043</td>
<td>0.524</td>
</tr>
<tr>
<td>Documentation</td>
<td>0.309</td>
<td>0.273</td>
<td>0.594</td>
</tr>
<tr>
<td>Overall adoption</td>
<td>0.241</td>
<td>0.193</td>
<td>0.573</td>
</tr>
</tbody>
</table>

Degree has positive effects on quality

Threshold of $r$ between 0.243 and 0.273
Analysis for H5 (size of organizations)

<table>
<thead>
<tr>
<th>OSS adoption factors</th>
<th>Small (N=30)</th>
<th>Large (N=30)</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of adoption</td>
<td>3.6851</td>
<td>3.6953</td>
<td>-0.034</td>
</tr>
<tr>
<td>Maturity level</td>
<td>3.0600</td>
<td>2.5800</td>
<td>1.905</td>
</tr>
<tr>
<td>Experience and skill</td>
<td>2.7833</td>
<td>2.6333</td>
<td>0.66</td>
</tr>
<tr>
<td>Select criteria</td>
<td>2.9000</td>
<td>2.7000</td>
<td>0.910</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SW development economics</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget</td>
<td>2.67</td>
<td>2.47</td>
<td>0.802</td>
</tr>
<tr>
<td>Productivity</td>
<td>3.13</td>
<td>2.47</td>
<td>4.106</td>
</tr>
<tr>
<td>Quality</td>
<td>2.87</td>
<td>2.67</td>
<td>0.869</td>
</tr>
</tbody>
</table>

Small organization has advantages to adopt OSS related to the maturity level and productivity.
Conclusion

❖ Contribution
  ▪ Provide an insight on relationships between
    • OSS adoption factors
      – Degree of adoption, maturity level, developers’ experience and skill, selection criteria
    • Software development economics
      – Budget, productivity, and quality

❖ Future work
  ▪ Impact of OSS reuse should be related to the improved measure of SPI success
  ▪ Need a thorough longitudinal study using the real data
Discussion(1/5)

- Contribution
  - Structure to get the result from initiating a hypothesis and statistically analyzing the data

- Critiques
  - Lack of the analysis on the sub-variables included in OSS adoption variables
  - Without consideration on the relationships among OSS adoption variables
    - For example, correlation coefficient between degree and select criteria is 0.845
Steps to construct the simulators

1. Define problem and goal to solve by simulation
2. Define the important qualitative parameters and relationship between them
3. Construct the simulator and run it
4. Do the literature review related to the problem
5. Getting the data for quantitatively specifying the parameters and the relationship between them
6. Analyze the results and validate it
Discussion (3/5)

- Required parameters for the simulator
  - Basically, software development economics are required
  - Quantitative information on psychological or detail relationships between parameters are required
    - Example) deadline(schedule pressure) - productivity
Parameter problem to construct the simulator

- SI companies in Korea rarely collect data
- Even if they collect the data, its focus is SW development economics
  - Most companies doesn’t show the interest on other parameters and doesn’t collect data

Parameter problem related to data directly connects with validation problem
Self-reflection

- Getting the quantitative data from the questionnaires is possible way
  - It should be used in the simulator only after proving that the parameter is appropriate through statistics
  - It’s demanding work, so it should be done just once
    - Constructing the unbiased questionnaires
    - Selecting the interviewees
    - Collecting and analyzing data
### OSS reused maturity levels

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>OSS reused motivation levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td><strong>Initial/chaotic</strong></td>
</tr>
<tr>
<td>Motivation/culture</td>
<td>Reuse discouraged</td>
</tr>
<tr>
<td>Planning for reuse</td>
<td>None</td>
</tr>
<tr>
<td>Breadth of reuse</td>
<td>Individual</td>
</tr>
<tr>
<td>Responsible for making reuse happen</td>
<td>Individual initiative</td>
</tr>
<tr>
<td>Process by which reuse is leveraged</td>
<td>Reuse process chaotic, unclear how reuse comes in</td>
</tr>
<tr>
<td>Metrics</td>
<td>No metrics on reuse level, pay-off, or costs</td>
</tr>
<tr>
<td><strong>Monitored</strong></td>
<td>Reuse encouraged</td>
</tr>
<tr>
<td>Grassroots activity</td>
<td>-work group activity</td>
</tr>
<tr>
<td>Shared initiative</td>
<td>Reuse questions raised at design reviews (after the fact)</td>
</tr>
<tr>
<td><strong>Coordinated</strong></td>
<td>Reuse enforced rewarded</td>
</tr>
<tr>
<td>Targets of opportunity</td>
<td>Department</td>
</tr>
<tr>
<td>Dedicated initiative</td>
<td>Design emphasis placed on OSS components</td>
</tr>
<tr>
<td><strong>Planned</strong></td>
<td>Reuse OSS indoctrinated</td>
</tr>
<tr>
<td>Business imperative</td>
<td>Division</td>
</tr>
<tr>
<td>Part of strategic plan</td>
<td>Dedicated group</td>
</tr>
<tr>
<td>Enterprise wide</td>
<td>Corporate group with division liaisons</td>
</tr>
<tr>
<td><strong>Ingrained</strong></td>
<td>Reuse OSS is the way do business</td>
</tr>
<tr>
<td>All software projects are generic for future reuse</td>
<td></td>
</tr>
<tr>
<td>All system utilities, software tools and accounting mechanisms instrumented to track reuse</td>
<td></td>
</tr>
</tbody>
</table>
AVE (Average Variance Extracted)

- AVE for correlation efficient $r$
  - Correlation efficient $r$ is valid if $\text{AVE}(r) > r^2$
  - Example

<table>
<thead>
<tr>
<th></th>
<th>Var 1</th>
<th>Var 2</th>
<th>Var 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Var 1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Var 2</td>
<td>0.9</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Var 3</td>
<td>0.8</td>
<td>0.7</td>
<td>1</td>
</tr>
<tr>
<td>AVE</td>
<td>0.8</td>
<td>0.4</td>
<td>0.45</td>
</tr>
</tbody>
</table>

$\text{AVE}(r)=0.8 < 0.81 = r_{12}^2$

Var 1 and var 2 have high possibility to measure the same things