

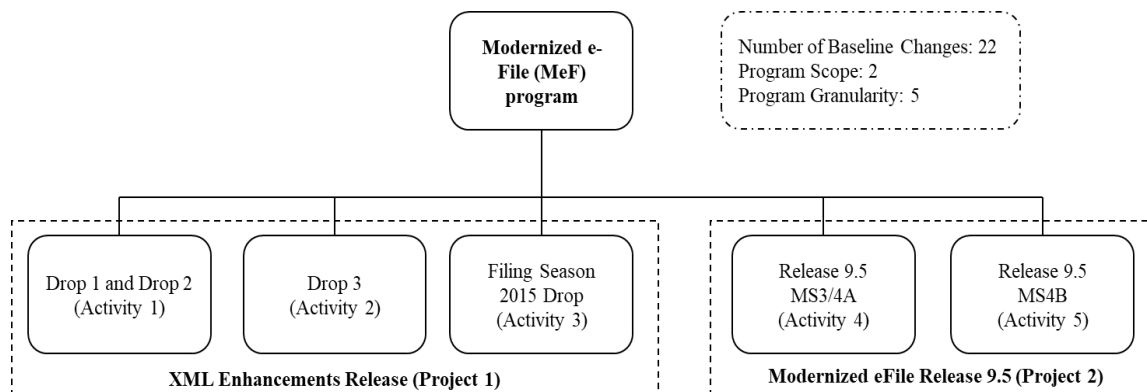
# Online Supplement

## Representative Example of a Federal Technology Program from the Study Sample

### Program Name: Internal Revenue Service’s Modernized e-File Program

The Modernized e-File program is a web-based system which allows corporate organizations and individuals to file their tax returns electronically with the Internal Revenue Service (IRS). This system hosts several corporate (e.g., Form 1120 series) and individual forms (e.g., Form 1040 series) on the web and reduces the burden for taxpayers while filing taxes.

**Figure A1. Illustration of the Modernized e-File Program in terms of Projects and Activities**



**Table A1. Description of the Projects and Activities in the Modernized e-File Program**

Project Title and Description	Activity Title and Description	Nature of Activity
<b>XML Enhancements Release</b> The XML (Extensible Markup Language) Enhancements Release coordinates the migration and implementation of MeF element names from non-standard XML to XML standard compliancy.	<b><i>Drop 1 and Drop 2</i></b> This activity involves the design of a technological solution to perform XML enhancements for the tax filing season of 2014.	Key Deliverable
	<b><i>Drop 3</i></b> This activity involves the development, testing, integration and deployment of XML enhancements for the tax filing season of 2014.	Production Release
	<b><i>Filing Season 2015 Drop</i></b> This activity involves the development, testing, integration and deployment of XML enhancements for the tax filing season of 2015.	Production Release
<b>Modernized eFile, Release 9.5</b> The primary objective of this project is to develop a technological solution that implements form changes for the tax filing season of 2015. These changes are needed because of the Foreign Account Tax Compliance Act (FATCA).	<b><i>Release 9.5 MS3/4A</i></b> This activity involves designing the solution to deliver form changes for the tax filing season of 2015.	System Design and Development
	<b><i>Release 9.5 MS4B</i></b> This activity focuses on the deployment of form changes for the tax filing season of 2015.	Production Release

**Table A2: Process for Proposing and Approving Baseline Changes in Federal Technology Programs<sup>1</sup>**

- **Step 1: Identify the Need for a Baseline Change**  
 The first step is to identify whether there is a need to change a program’s current baseline. This step is carried out jointly by the contractor(s) associated with the program and the agency Program Management Office (PMO). A comparison of the program’s existing budget and duration with the remaining work to be completed in the program (i.e., program scope) helps in identifying the need for a baseline change (Small Business Administration 2011). Particularly, if a program’s existing budget and duration is inadequate to complete the remaining work in the program,<sup>2</sup> its baseline may be modified, subject to approval from the agency PMO and Chief Information Officer (CIO).
- **Step 2: Raise Baseline Change Request with Agency PMO**  
 Next, the contractor(s) associated with the program raises a Baseline Change Request (BCR) with the agency PMO. This request contains details about the program’s new baseline (i.e., the program’s new budget, schedule and scope estimates), the reasons for requesting a new baseline and a detailed comparison of the program’s existing baseline with the new baseline.
- **Step 3: Validation and Acceptance (or Rejection) of a New Baseline**  
 The agency PMO validates the rationale for a baseline change request and evaluates the resource requirements and risks associated with the new baseline requested by the contractor(s). Specifically, the agency PMO examines whether (i) the request for a new baseline is justified, and (ii) new resource requirements (e.g., modified schedule and budget estimates, technological infrastructure, personnel requirements) are available and adequate to complete the remaining work in the program.
- **Step 4: Approval of New Baseline**  
 Subsequently, following approval of the baseline change request by the agency PMO, the assessment findings are presented to agency CIO for final approval.

**Table A3. Examples of Baseline Changes in Federal Technology Programs from Study Sample**

Program Description	Examples of Baseline Changes
<p>The Commerce Business System is a web-based portal that serves as the central point of access for the Department of Commerce's business applications and financial reporting requirements.</p>	<p>This program experienced <u>two</u> baseline changes during its execution:</p> <p>(i) There were modifications in the requirements and design and development activities of two projects in the program, namely, System for Contract Award Management and Upgradation of System Middleware. Consequently, the program’s original budget and schedule were revised to account for these changes.</p> <p>(ii) Two new projects were added to the program, namely, Automated Standard Application for Payments and Grant Transfer Application System. The baseline was changed to reflect the revised budget and schedule associated with the addition of two new projects to the program.</p>
<p>The Executive Information and Decision Support (EIDS) system consists of a database and several decision support tools to manage military health care operations in the Department of Defense.</p>	<p>This program experienced <u>one</u> baseline change to account for system deployment issues associated with the accounting module of EIDS. These deployment issues consisted of unanticipated coding errors and software failures which, in turn, was an outcome of inadequate system testing before deployment.</p>

<sup>1</sup> Specific agencies may follow slight variations of the above steps associated with the rebaselining process.

<sup>2</sup> Note that a new baseline is not requested to cover small cost and/or schedule slippages and to accommodate for minor modifications in a program’s scope. For example, the Department of Justice does not permit a baseline change request to be raised unless the cost and/or schedule slippage for the program exceeds the tolerant range of ±10%.

**Table A4. Measurement of Program Management Competency in Federal IT Dashboard**

Rating <sup>†</sup>	Description
1	FAC-P/PM senior-level or DAWIA level 3 certification with at least 4 years of project management experience (within last ten years) and at least 1 year of experience in federal technology programs
2	FAC-P/PM mid-level or DAWIA level 2 certification with at least 2 years of project management experience (within last five years)
3	FAC-P/PM entry-level or DAWIA level 1 certification with at least 1 year of project management experience (within last five years)
4	Other certification with 4 or more years of project management experience (within last five years)
5	Other certification with between 2 and 4 years of project management experience (within last five years)
6	Other certification with less than two years of project management experience (within last five years)
7	No certification, but with 4 or more years of project management experience (within last five years)
8	No certification, but with between 2 and 4 years of project management experience (within last five years)
9	No certification, but with less than two years of project management experience (within last five years)

Notes: The federal government has established the Federal Acquisition Certification for Program and Project Managers (or FAC-P/PM) to track the necessary competencies required by managers to handle projects for its civilian agencies. Similarly, the Defense Acquisition Workforce Improvement Act (DAWIA) requires managers working for the defense agencies to have a similar certification that focuses on program management competency.

† For the ease of interpretation, we reverse coded the program management competency levels.

**Table A5. Pairwise Correlations and Descriptive Statistics**

Variable Names	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1 Number of Baseline Changes	1																			
2 Program Scope	.18	1																		
3 Program Granularity	.16	.46	1																	
4 Program Mgmt. Competency	.08	.05	.07	1																
5 Execution Methodology: Agile	.13	.07	.02	.11	1															
6 Execution Methodology: Hybrid	-.14	-.03	.06	-.03	-.32	1														
7 Program Duration	.10	.22	.30	.13	-.02	.01	1													
8 Program Budget	-.02	.05	.11	.14	-.03	.11	.40	1												
9 Program DME Percentage	.02	-.04	.11	.11	.03	-.04	.12	.22	1											
10 Program Type: Major	-.05	-.01	.02	.14	.04	-.03	-.04	.02	.12	1										
11 Legislative Mandate	.11	.16	.16	.03	.17	-.12	-.03	.01	.01	.13	1									
12 Audit Finding	.10	.03	.04	.01	.01	-.07	-.03	-.05	.14	-.03	.12	1								
13 Agency Plan	.10	-.01	-.05	.14	.03	-.02	.03	.09	.21	.11	-.04	.08	1							
14 Presidential Priority	.04	.06	.01	.00	.22	-.07	.00	-.04	-.00	.05	.21	.10	.03	1						
15 Number of Contracts	.03	.16	.03	.09	.04	-.10	.10	.12	.15	.21	.14	.18	.11	-.01	1					
16 Number of Contractors	-.06	.12	-.01	.09	-.04	-.06	.02	.07	.05	.15	.10	.04	.13	-.10	.42	1				
17 Modular Contracting	-.03	-.09	.08	.13	.04	-.07	.03	-.04	.20	.28	.11	.03	.01	.08	-.01	.08	1			
18 Percent Fixed Price Contracts	.09	.10	-.01	.11	.05	-.03	-.02	-.12	-.06	-.05	-.05	.10	.06	.08	.14	-.02	.08	1		
19 Average Contractor Experience	-.06	-.07	-.06	-.05	-.13	-.06	.01	.02	.08	.04	.04	-.01	.13	.04	.04	-.04	-.15	.08	1	
Mean	3.14	3.04	15.47	7.00	0.25	0.24	3.07	62.64	0.50	0.41	0.53	0.23	0.74	0.21	6.28	1.1	0.37	0.51	15.6	
Standard Deviation	3.47	3.52	23.13	2.33	0.43	0.43	3.14	224	0.31	0.49	0.50	0.42	0.44	0.41	10.92	0.63	0.44	0.35	28.9	
Minimum	0	1	0	1	0	0	0.17	0.02	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	27	29	191	9	1	1	23.01	2587	1	1	1	1	1	1	4	9	1	1	252	
Number of Observations	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240

Note: Correlation values greater than |0.12| are significant at 0.05 level

**Table A6. First Stage Results Predicting Program Granularity and Program Management Competency**

	(1)	(2)
	<b>Dependent Variable:</b> <i>Program Granularity</i>	<b>Dependent Variable:</b> <i>Program Management Competency</i>
<b><i>Instrumental Variables</i></b>		
Prior-year Program Granularity	0.026 (0.008)***	
Prior-year Percent Short Activities	3.638 (1.557)**	
Prior-year Program Mgmt. Competency		0.512 (0.158)***
Same-year Same-competency Programs		0.194 (0.022)***
<b><i>Control Variables</i></b>		
Program Scope	0.038 (0.017)**	0.035 (0.032)
Execution Methodology: Agile	-0.048 (0.113)	0.340 (0.305)
Execution Methodology: Hybrid	0.018 (0.149)	-0.179 (0.286)
Program Duration	0.020 (0.028)	-0.013 (0.059)
Program Budget	0.000 (0.000)	0.001 (0.000)**
Program DME Percentage	0.310 (0.160)**	0.269 (0.456)
Program Type: Major	0.191 (0.168)	0.025 (0.443)
Program Source: Legislative Mandate	0.099 (0.099)	0.288 (0.216)
Program Source: Presidential Priority	-0.049 (0.103)	-0.335 (0.263)
Program Source: Agency Plan	-0.072 (0.110)	0.337 (0.352)
Program Source: Audit Finding	0.159 (0.133)	-0.135 (0.226)
Number of Contracts	-0.002 (0.006)	-0.008 (0.010)
Number of Contractors	-0.082 (0.069)	0.084 (0.194)
Modular Contracting	0.161 (0.107)	0.422 (0.326)
Percentage Fixed Price Contracts	0.158 (0.183)	0.573 (0.541)
Average Contractor Experience	-0.001 (0.001)	-0.001 (0.003)
Intercept	0.914 (0.538)*	7.469 (0.803)***
<i>Agency Fixed Effects</i>	Yes	Yes
<i>Program Start Year Fixed Effects</i>	Yes	Yes
<i>F-test for Weak Instruments (p value)</i>	23.27 (p<0.01)	47.00 (p<0.01)
<i>Hansen J Statistic (p value)</i>	1.288 (p=0.26)	0.061 (p=0.80)
<i>R<sup>2</sup></i>	0.71	0.60
<i>Number of Observations</i>	240	240

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1; two-tailed tests used to report statistical significance levels.  
Robust standard errors clustered by agency and program start year dummies in parentheses.

### Using Gaussian Copula Approach to Correct for Potential Endogeneity of Program Granularity and Program Management Competency

In addition, as an alternative way to account for endogeneity of *Program Granularity* and *Program Management Competency*, we use the Gaussian copula approach suggested by Park and Gupta (2012) and widely adopted in prior research (e.g., Atefi et al. 2018). The copula approach differs from traditional instrumental variable approach to correct for endogeneity in that it does not require the use of instrumental variables to partial out the exogenous component of the endogenous variable. Instead, the approach models the joint distribution of the endogenous variable and the error term in the main model through a control function term. The potentially endogenous regressor is represented as a random variable consisting of an exogenous component which is non-normally distributed and an endogenous component that is normally distributed. With a normally distributed error term, a central identification requirement is that the endogenous regressor is non-normally distributed. This will allow the variation in the endogenous regressor to be separated from the variation in the error term.

The copula terms for *Program Granularity* and *Program Management Competency* are obtained as:  $Program\ Granularity_{Copula} = \Phi^{-1} [H(Program\ Granularity)]$ , and  $Program\ Management\ Competency_{Copula} = \Phi^{-1} [H(Program\ Management\ Competency)]$ . In this equation,  $\Phi^{-1}$  is the inverse of the cumulative normal distribution function.  $H(Program\ Granularity)$  and  $H(Program\ Management\ Competency)$  represent the empirical distribution functions of Program Granularity and Program Management Competency, respectively.

In our sample, the non-normal distributional assumption of the potentially endogenous regressors are supported by the Shapiro Wilk test ( $W = 0.62$ ,  $p < 0.01$  for *Program Granularity* and  $W = 0.94$ ,  $p < 0.01$  for *Program Management Competency*). We therefore proceed with inclusion of the copula terms in our full model to examine sign and the statistical significance associated with the moderating roles of *Program Granularity* and *Program Management Competency*. As shown in Table A7, our results following the inclusion of these copula terms remain highly consistent with our main results as well as the instrumental variables estimation, indicating their robustness.

**Table A7. Results from Gaussian Copula Approach Including Copula Correction Terms for Program Granularity and Program Management Competency**

	<b>Dependent Variable:</b> <i>Number of Baseline Changes</i>
	Using Gaussian Copula Correction Approach (Park and Gupta 2012)
<b>Main effects</b>	
Program Scope	0.067 (0.020)**
Program Granularity	0.004 (0.003)
Program Mgmt. Competency	-0.076 (0.154)
Execution Methodology: Agile	0.280 (0.143)*
Execution Methodology: Hybrid	-0.070 (0.170)
<b>Moderation effects</b>	
Program Scope × Program Granularity	-0.001 (0.000)**
Program Scope × Program Mgmt. Competency	-0.022 (0.010)**
Program Scope × Execution Methodology: Agile	-0.011 (0.027)
Program Scope × Execution Methodology: Hybrid	-0.002 (0.021)
<b>Control variables</b>	
Program Duration	0.033 (0.025)
Program Budget	-0.000 (0.000)
Program DME Percentage	-0.120 (0.176)
Program Type: Major	0.137 (0.175)
Program Source: Legislative Mandate	-0.059 (0.103)
Program Source: Audit Finding	-0.147 (0.124)
Program Source: Agency Plan	0.390 (0.124)***
Program Source: Presidential Priority	0.008 (0.126)
Number of Contracts	0.010 (0.005)**
Number of Contractors	-0.082 (0.092)
Modular Contracting	-0.055 (0.114)
Percentage Fixed Price Contracts	-0.023 (0.155)
Average Contractor Experience	-0.001 (0.004)
Copula Correction (Program Granularity)	0.074(0.105)
Copula Correction (Program Management Competency)	0.385(0.412)
Intercept	2.853 (0.444)***
<i>Agency Fixed Effects</i>	Yes
<i>Program Start Year Dummies</i>	Yes
<i>Pseudo-R<sup>2</sup></i>	0.534
<i>Log Pseudolikelihood</i>	-455.381
<i>Number of Observations</i>	240

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1; two-tailed tests used to report statistical significance levels.

Robust standard errors clustered by agency and program start year dummies in parentheses.

### Addressing Endogeneity of Agile Execution Methodology Using Treatment Effects Model

The treatment effects model attempts to address endogeneity concerns for a binary variable through a control function approach (Wooldridge 2010, Cameron and Trivedi 2005) and we use this model to estimate the effect of agile execution methodology on the number of baseline changes. The estimation of the model is carried out in two stages. In the first stage, a probit model is run with suitable instrumental variables (and other control variables) to predict the likelihood of a program using agile execution methodology. From the first stage model, a selection hazard,  $\Lambda$ , is generated, which is then included in the second stage model estimating the number of baseline changes. Intuitively, the selection hazard in the second stage model can be thought of as a parameter that controls for unobservables that impact both the choice of agile execution methodology and the number of baseline changes in a program. The two stages are estimated jointly using STATA's *etregress* command.

**(a) Estimation of First Stage Probit Model:** Following recommendations in recent studies (e.g., Certo et al. 2016), we include additional variables, namely, *Prior Years' Agile Programs* and *Same Year Agile Programs*, that are relevant and are likely to satisfy the exclusion restriction in the first stage of probit model along with control variables. Below, we provide the theoretical and empirical support for inclusion of the two additional variables in the first stage probit model:

- ***Prior Years' Agile Programs:*** This variable represents *a count of the total number of programs using agile execution methodology that were started in prior years by the same agency as the agency executing the focal program*. Given the push from federal government to use agile execution methodology in technology programs (Miller and Ward 2016, Moczar 2013, Deloitte 2017), agencies with a historically lower count of programs that deploy agile execution methodology may have greater motivation to increase this count for their current and future technology programs in order to be consistent with the trends in federal government marketplace. However, this variable, capturing the number of other programs using agile execution methodology and were started in prior years, would not directly affect the number of baseline changes of a focal program, except for its influence on the choice of agile execution methodology for the focal program.
- ***Same Year Agile Programs:*** This variable represents *a count of the total number of agile programs that were started in the same year by the same agency as the one executing the focal program*. The rationale behind using this instrumental variable is that the likelihood for a program to use agile execution methodology may be higher if it has been started in the same year when an agency has a greater number of agile programs in its overall portfolio of programs. That is, when there is a greater number of agile programs started by an agency in a given year, the likelihood is higher for the focal program to use agile execution methodology. However, as this variable is not an observed characteristic or attribute of the focal program, we do not expect this variable to impact the number of baseline changes of a focal program directly, except through its influence on the choice of agile execution methodology for the focal program.

Finally, to account for observed sources of heterogeneity across federal technology programs and consistent with recommendations in prior literature (e.g., Ramasubbu et al. 2015, Austin and Devin 2009) as well as your suggestion that program characteristics may potentially affect the choice of agile execution methodology versus other methodologies in the program, we also include the control variables in our first stage analysis.

Table A8 presents results from the first stage of the endogenous treatment effects model. Consistent with our theoretical arguments, we find that agencies with lower values of *prior years' agile programs* are more likely to choose agile execution methodology in a program ( $\beta=-0.126$ ,  $p<0.05$ ) and vice-versa, and higher values of *same year agile programs* increases the likelihood to choose agile execution methodology ( $\beta=0.217$ ,  $p<0.01$ ).

**Table A8. First Stage Probit Model Predicting Agile Execution Methodology**

<b>Dependent Variable—Execution Methodology: Agile</b>	
Prior Years' Agile Programs	-0.126 (0.061)**
Same Year Agile Programs	0.217 (0.049)***
Program Duration	0.011 (0.059)
Program Budget	-0.000 (0.001)
Program DME Percentage	0.566 (0.375)
Program Type: Major	0.380 (0.239)
Program Source: Legislative Mandate	0.391 (0.215)*
Program Source: Audit Finding	-0.085 (0.245)
Program Source: Agency Plan	0.138 (0.240)
Program Source: Presidential Priority	0.620 (0.230)***
Number of Contracts	-0.004 (0.010)
Number of Contractors	-0.136 (0.209)
Modular Contracting	-0.081 (0.246)
Percentage Fixed Price Contracts	-0.071 (0.292)
Average Contractor Experience	-0.020 (0.008)**
Intercept	-3.562 (0.967)***
<i>Program Start Year Dummies</i>	Yes
<i>Log Pseudolikelihood</i>	-104.295
<i>Pseudo-R<sup>2</sup></i>	0.221
<i>Number of Observations</i>	240

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1; two-tailed tests used to report statistical significance levels.  
Robust standard errors clustered by agency and program start year dummies in parentheses.

**References**

Atefi Y, Ahearne M, Maxham III, JG, Donovan DT, Carlson BD (2018) Does selective sales force training work? *Journal of Marketing Research* 55(5): 722-737.

Austin RD, Devin L (2009) Weighing the benefits and costs of flexibility in making software: Towards a contingency theory of the determinants of development process design. *Information Systems Research* 20(3): 462-477.

Cameron AC, PK Trivedi (2005) *Microeconometrics: Methods and Applications*. Cambridge University Press.

Certo ST, Busenbark JR, Woo HS, Semadeni M (2016) Sample selection bias and Heckman models in strategic management research. *Strategic Management Journal* 37(13): 2639-2657.

Deloitte (2017) [Agile by the numbers: A data analysis of Agile development in the U.S. federal government](#). Accessed: October 15, 2019.

Department of Justice (2010) [Information Technology Investment Baseline Management Guide](#). Accessed: December 16, 2019.

Miller S, Ward D (2016) [Update 2016: Considerations for Using Agile in DoD Acquisition \(No. CMU/SEI-2016-TN-001\)](#). Carnegie Mellon University, Pittsburgh PA, United States.

Moczar L (2013) [Why agile isn't working: bringing common sense to agile principles](#). *CIO*. Accessed: January 23, 2020.

Park S, Gupta S (2012) Handling endogenous regressors by joint estimation using copulas. *Marketing Science* 31(4): 567-586.

Ramasubbu N, Bharadwaj A, Tayi GK (2015) Software process diversity: conceptualization, measurement, and analysis of impact on project performance. *MIS Quarterly* 39(4): 787-807.

Small Business Administration (2011) [IT Investment Performance Baseline Management Policy](#). Accessed: December 16, 2019.

Wooldridge JM (2010) *Econometric Analysis of Cross Section and Panel Data*. 2<sup>nd</sup> Edition. MIT Press.