ONLINE APPENDIX

TRANSFERRING KNOWLEDGE BY TRANSFERRING INDIVIDUALS: INNOVATIVE TECHNOLOGY USAGE AND ORGANIZATIONAL PERFORMANCE IN MULTI-UNIT FIRMS

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Sample Selection Model

To conduct a formal Heckman type test for selection bias in the presence of endogenous regressors, we use the procedure developed by Semykina and Wooldridge (2010) for panel data with fixed effects. This procedure entails estimating a first stage probit selection model using the Mundlak (1978) procedure of including time-averaged variables to control for fixed effects, and then including the inverse Mills ratio (IMR) from this model in a 2SLS model. If the estimated coefficient on the IMR is statistically significant, this indicates the presence of sample selection bias.

A probit model cannot be estimated using a standard fixed effects model due to the incidental parameters problem. We are also unable to use the *probitfe* program in Stata that corrects for this problem, because our data are not organized as a panel. Instead, each observation is at the job assignment level. We therefore rely on the Mundlak (1978) procedure of including time-averaged values of the right-hand side variables in the probit model to control for unit fixed effects. Per Semykina and Wooldridge (2010), the probit selection model must include an additional exogenous variable that serves as an instrument as well as all of the exogenous variables in the 2SLS model, including the instruments used in that model; the probit model cannot include any variables that are endogenous in the 2SLS model (see also Wooldridge, 2002, pp. 568-9). The inverse Mills ratio estimated from the probit model is then included in the 2SLS model, and the additional instrument in the selection equation is included as an instrument in the 2SLS estimation together with the other instruments in that model. Because this is a test rather than a correction for sample selection bias, it is not necessary to adjust the standard errors in the 2SLS model to account for the inverse Mills ratio being a predicted value derived from the probit selection model (Semykina and Wooldridge, 2010).

To construct the sample for the probit selection model, we organize the data by year. For each year, we include all engineers who began a new assignment during that year as well as all engineers who were working in OILCOMP on a continuing assignment during that year (and therefore could potentially have been hired into available positions but were not). The dependent variable in the first stage probit equation, *engineer newly hired*, measures in each year whether or not an engineer was newly hired during that year by the unit in which the engineer was working at the end of the year. For each year, engineers who were hired into a unit during that year receive a value of 1 for the dependent variable and engineers who were not hired into any unit during that year receive a value of 0. Although Semykina and Wooldridge (2010) recommend estimating the IMR separately for each year, we do not have enough observations per year to enable the annual probit models to converge. Instead, we include all years together in the probit model, compute the time-averaged values per unit of the right-hand side variables following Mundlak (1978), and include these variables in the model.

As an instrument in the probit model, we use the innovative technology expertise of the engineers in each unit in the prior year, *prior year engineer innovative technology experience per unit*. The innovative technology expertise that a unit has among the engineers working in the unit might affect its decision to hire. For example, if the engineers in a unit have expertise in fewer innovative technologies, the unit might seek to hire engineers who have greater breadth of expertise. The instrumental variable is constructed as the count of the number of different innovative technologies used in the past by all engineers working in a unit in the prior year, which is similar to the *engineer innovative technology experience* variable except that the new variable measures engineer experience at the unit level and in the prior year rather than the current year. The new variable would not directly affect well drilling costs in the current year because the engineers working in each unit differ from year to year.

Table A1 reports the results. In the first stage model, the coefficient on *prior year engineer innovative technology experience per unit* is negative and statistically significant, indicating that units with less innovative technology expertise among its engineers in the prior year are more likely to hire. However, in the second stage 2SLS model, the inverse Mills ratio is not statistically significant (p-value=0.1187) and the explanatory variables are highly significant with the same signs and similar

coefficient estimates to the original 2SLS model, suggesting that sample selection bias does not affect our estimates.[1]

REFERENCES

Mundlak Y (1978) On the pooling of time series and cross section data. *Econometrica* 46: 69-85.

Semykina A, Wooldridge JM (2010) Estimating panel data models in the presence of endogeneity and selection. *Journal of Econometrics* 157: 375-380.

[1] The 2SLS model passes the underidentification test (Kleibergen-Papp rk LM statistic value of 48.047, p=0.000), the weak identification test (based on Cragg-Donald Wald statistic of 8.460, which exceeds the Stock-Yogo critical value of 7.77 for 10% maximal bias and p<0.05), and the overidentification test (the Hansen J statistic is 3.90, p=0.2724).

Table A1. Two-stage Sample Selection Estimates

	Stage 1 - PROBIT Engineer newly hired	Stage 2 - IV 2SLS Log(total well cost per meter)
Experience in HQ	-0.0281	0.1011***
	(0.1166)	(0.0269)
Experience with different reserve types	-0.0298	-0.0132**
	(0.0291)	(0.0044)
Offshore and onshore experience	0.0284	0.0489***
	(0.0761)	(0.0117)
Days on assignment[a]	-0.4403***	0.0082
	(0.0431)	(0.0071)
Seniority level	-0.0096	-0.0078*
	(0.0256)	(0.0031)
Seniority potential	0.0124	-0.0013
	(0.0343)	(0.0039)
Total time in firm[a]	0.0323	0.0245***
	(0.0272)	(0.0040)
Prior experience outside of firm	-0.0161	0.0037
	(0.0556)	(0.0067)
Size (# of wells drilled)[a]	0.1992+	-0.9483***
	(0.1054)	(0.0143)
Top international drilling contractor	-0.0361***	0.0044**
	(0.0096)	(0.0016)
Total well cost[a]	0.0014	0.8461***
	(0.0755)	(0.0109)
Exploration well	0.0326	0.0079
	(0.0207)	(0.0066)
Offshore rig	0.0086	0.0049***
	(0.0055)	(0.0010)
Total non-productive days[a]	-0.2637***	-0.0589***
	(0.0483)	(0.0093)
Oil price in start year	0.0197***	-0.0000
	(0.0019)	(0.0004)
Job specification: completion and integration	-0.0473	-0.0047
	(0.0510)	(0.0059)
Job specification: commercial	-0.0670	0.0214
	(0.1615)	(0.0207)
Job specification: other engineering	0.1516	0.0221
	(0.1153)	(0.0137)
Co-worker high level of innov tech exper	0.7369***	-0.0478***
	(0.0909)	(0.0118)
Prior year engineer innov technology experience per unit	-0.0388*	
	(0.0162)	
# of times unit used innovative technologies in prior year	-0.1404***	
	(0.0359)	
Managerial experience	0.0040	
	(0.0159)	
# previous times engineer used his/her most frequently used technology	-0.0049	
	(0.0114)	
Experience with complex wells	-0.0087	
	(0.0540)	
# of times unit used innov technologies in prior year x managerial experience	0.0016	
	(0.0072)	
Unit innovative technology use		-0.1336***
		(0.0372)
Engineer innov technology experience		-0.0420***
		(0.0090)

Unit technology x engineer technology		0.0217**
		(0.0067)
Inverse Mills ratio		0.1635
		(0.1187)
Constant	8.7659	
	(6.2296)	
Year dummies	YES	YES
Unit (Country) fixed effect	NO	YES
Average variables	YES	NO
Observations	4612	3197
Pseudo loglikelihood	-2379.8731	
R^2		0.840
Adjusted R^2		0.837

Standard errors in parentheses: $^{+}$ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Subsample Correlation Coefficients

Table A2. Correlation Coefficients New Technology Introduction Subsample

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Total well cost per meter	1.00																					
2	Experience in HQ	-0.5*	1.00																				
3	Exp with different reserve types	0.21*	0.12*	1.00																			
4	Off/onshore exp.	-0.21*	0.00	0.02	1.00																		
5	Days on assignment	-0.27*	0.11*	-0.15*	0.1*	1.00																	
6	Seniority level	0.08*	-0.01	-0.07*	-0.07*	-0.03	1.00																
7	Seniority potential	-0.03	0.04	0.00	-0.16*	0.02	0.17*	1.00															
8	Total time in firm	-0.01	-0.1*	0.44*	0.13*	-0.06*	-0.29*	0.08*	1.00														
9	Prior exp.outside firm	-0.11*	0.09*	0.11*	0.01	0.12*	-0.29*	0.4*	0.19*	1.00													
10	Size (# of wells drilled)	0.12*	-0.37*	-0.13*	-0.14*	0.5*	-0.04	0.07*	0.02	0.04	1.00												
11	Top drilling contractor	0.03	0.00	-0.07*	0.04	0.45*	0.00	0.00	-0.16*	0.15*	0.22*	1.00											
12	Total well cost	0.64*	-0.53*	0.05*	-0.21*	0.24*	0.02	0.01	-0.06*	0.01	0.77*	0.31*	1.00										
13	Exploration well	0.04	-0.09*	-0.02	-0.29*	0.3*	-0.02	0.04	-0.15*	0.15*	0.39*	0.47*	0.44*	1.00									
14	Offshore rig	0.31*	-0.32*	-0.09*	-0.41*	0.28*	0.01	0.12*	0.03	0.02	0.74*	0.26*	0.64*	0.47*	1.00								
15	Total non-productive days	-0.09*	-0.14*	-0.18*	0.35*	0.54*	-0.03	-0.11*	-0.15*	0.1*	0.37*	0.5*	0.35*	0.22*	0.09*	1.00							
16	Oilprice in start year	-0.04	0.18*	-0.01	0.16*	0.03	0.03	-0.01	0.09*	-0.1*	-0.17*	-0.14*	-0.21*	-0.38*	-0.15*	0.02	1.00						
17	Job spec.: comp./ integration	0.03	0.05	0.06*	-0.09*	-0.01	0.14*	0.26*	0.12*	0.28*	-0.01	-0.02	0.00	-0.04	0.02	-0.1*	0.02	1.00					
18	Job spec.: commercial	0.01	-0.04	0.01	0.08*	0.00	0.01	-0.06*	0.03	0.02	0.00	0.00	0.00	-0.03	0.00	0.05	-0.01	-0.09*	1.00				
19	Job spec.: other engineering	0.03	-0.07*	-0.07*	-0.14*	0.01	0.13*	0.09*	-0.08*	0.05*	0.05*	0.13*	0.09*	0.19*	0.1*	0.02	-0.09*	-0.14*	-0.03	1.00			
20	Co-worker high level innov tech exp	0.39*	-0.24*	0.22*	-0.36*	-0.23*	0.03	0.03	0.06*	-0.05*	0.1*	-0.17*	0.31*	0.1*	0.16*	-0.37*	-0.03	0.07*	-0.03	0.00	1.00		
21	Unit innov technology use	0.08*	0.05*	0.09*	-0.06*	0.16*	-0.03	-0.05	-0.21*	0.17*	0.05*	0.39*	0.29*	0.6*	0.01	0.34*	-0.28*	-0.06*	-0.03	0.13*	0.16*	1.00	
22	Engineer innov technology exp	0.00	0.38*	0.56*	0.16*	-0.13*	-0.19*	0.02	0.38*	0.21*	-0.2*	-0.11*	-0.11*	-0.16*	-0.2*	-0.1*	0.23*	0.07*	-0.01	-0.07*	0.11*	0.16*	1.00

* $p<0.05$ Variables in log form: days on assignment, total time in firm, size, total well cost, total non-productive days

Table A3. Correlation Coefficients No New Technology Introduction Subsample

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Total well cost per meter	1.00																					
2	Experience in HQ	0.31*	1.00																				
3	Exp with different reserve types	0.29*	0.26*	1.00																			
4	Off/onshore exp.	-0.09*	-0.16*	0.32*	1.00																		
5	Days on assignment	-0.01	0.06*	-0.06*	-0.06*	1.00																	
6	Seniority level	0.1*	0.01	-0.25*	-0.17*	-0.08*	1.00																
7	Seniority potential	-0.01	0.03	-0.07*	-0.09*	0.03	0.2*	1.00															
8	Total time in firm	0.00	0.07*	0.63*	0.3*	0.05	-0.45*	-0.13*	1.00														
9	Prior exp.outside firm	-0.06*	0.00	0.14*	0.07*	0.02	-0.34*	0.38*	0.1*	1.00													
10	Size (# of wells drilled)	-0.36*	-0.23*	0.07*	0.12*	0.3*	-0.1*	0.02	0.07*	0.05*	1.00												
11	Top drilling contractor	0.12*	0.06*	0.13*	-0.18*	0.3*	-0.01	0.03	0.01	-0.01	0.55*	1.00											
12	Total well cost	0.52*	-0.06*	0.3*	0.06*	0.24*	0.01	0.00	0.01	0.03	0.54*	0.51*	1.00										
13	Exploration well	-0.17*	-0.11*	0.07*	-0.04	0.04	-0.11*	0.03	-0.03	0.11*	0.56*	0.4*	0.32*	1.00									
14	Offshore rig	0.11*	-0.07*	0.11*	0.02	0.31*	-0.05*	-0.02	0.01	0.02	0.6*	0.74*	0.6*	0.38*	1.00								
15	Total non-productive days	-0.17*	-0.34*	0.04	0.27*	0.14*	-0.08*	0.03	0.00	0.13*	0.63*	0.22*	0.55*	0.45*	0.32*	1.00							
16	Oilprice in start year	0.02	-0.03	-0.17*	0.09*	0.15*	0.02	0.00	-0.01	-0.15*	-0.13*	-0.05*	-0.11*	-0.18*	0.01	-0.08*	1.00						
17	Job spec.: comp./ integration	0.06*	0.17*	0.04	-0.03	0.1*	0.1*	0.14*	0.04	0.14*	-0.05*	0.01	-0.02	-0.12*	-0.04	-0.08*	-0.01	1.00					
18	Job spec.: commercial	0.00	-0.01	0.04	0.04	0.05*	-0.13*	-0.08*	0.06*	0.02	0.01	0.01	0.02	-0.05*	0.02	-0.01	-0.02	-0.07*	1.00				
19	Job spec.: other engineering	0.07*	-0.04	-0.06*	0.02	-0.08*	0.06*	0.02	-0.07*	-0.04	0.00	-0.02	0.07*	0.02	0.00	0.03	-0.07*	-0.12*	-0.03	1.00			
20	Co-worker high level innov tech exp	0.25*	-0.39*	0.16*	0.34*	-0.04	0.04	-0.07*	0.08*	-0.08*	0.00	0.03	0.29*	-0.2*	0.1*	0.08*	0.22*	-0.02	0.04	0.02	1.00		
21	Unit innov technology use	0.32*	-0.24*	0.24*	0.33*	-0.13*	0.04	-0.02	-0.02	0.06*	0.12*	-0.07*	0.54*	0.07*	0.06*	0.38*	-0.11*	-0.08*	0.02	0.13*	0.56*	1.00	
22	Engineer innov technology exp	0.34*	0.34*	0.71*	0.49*	-0.03	-0.25*	-0.08*	0.5*	0.11*	-0.04	-0.01	0.27*	-0.14*	0.07*	0.04	-0.01	0.09*	0.04	-0.04	0.32*	0.35*	1.00

* $p<0.05$ Variables in log form: days on assignment, total time in firm, size, total well cost, total non-productive days