Supplemental Materials for Bruce A. Blonigen and Christopher T. Taylor, "R&D Intensity and Acquisitions in High Technology Industries: Evidence from the U.S. Electronic and Electrical Equipment Industries," The Journal of Industrial Economics 48 (1), March 2000, pp. 47-70

APPENDIX of SUPPLEMENTARY MATERIALS

This appendix includes 10 tables reporting empirical results referred to, but not reported in the text. We also provide further details on the GMM estimation procedure, as well as the random-effects and "between" negative binomial models we use in the paper.

On page 15 of the text, we state: "A variety of other specification were estimated as sensitivity checks, including estimation of OLS, probit and Poisson models, as well as a variety of alternative variable matrices." Tables A1-A4 below document the statistical results from these specifications.

On page 16 of the text, we state: "In addition, using a firm's sales as a proxy for size rather than total assets and/or defining R&D intensity as the ratio of R&D expenditures to sales yields qualitatively identical results." Table A5 below documents the statistical results from this specification.

On page 16 of the text, we state: "To address this we created annual calendar year time dummies where we allocated the share of the dummy effect according to how the firm's fiscal year overlapped with the calendar year. We could not reject the hypothesis that these time dummies are jointly insignificant at the 5 percent significance level and had little impact on our other estimated coefficients. We also constructed a variable of total U.S. domestic acquisition activity (excluding the electronic and electrical equipment industries to avoid endogeneity) that corresponded to each firm's fiscal year. Including this variable does not significantly alter any of our coefficient signs and was typically insignificant in most specifications we tried." Table A6 and A7 below document the statistical results from these specifications.

In footnote 18 on page 18 of the text, we state: "Including 4-digit industry effects in the negative binomial specification, both with and without lagged regressors, yields very similar results to the GMM estimates that control for fixed-effects below." Table A8 below documents the statistical results from this specification.

On page 20-21 of the text, we state: "Other sensitivity tests included eliminating firms with no acquisition activity in the data set. One might be concerned these firms' acquisition decisions follow a completely specification than firms that do acquire. However, there was virtually no impact on our estimated coefficients. Another concern may be that the SIC listed by Compustat may be misleading and we are including firms that may be distribution firms rather than high-technology electronics manufacturers. Distribution firms would have negligible R&D expenditures and our results on R&D intensity may just be suggesting that distribution firms acquire more than manufacturing firms. We ran a sample which excludes observations where R&D intensity is less than 2.5 percent and this leads to qualitatively identical results to those using the full sample." Tables A9 and A10 below document the statistical results from these specifications.

On page 22, we indicate that we report in this appendix the results from the negative binomial between estimator when cash flow is included as a regressor. Table A11 reports these results.

In footnote 19, we indicate that we report in this appendix the results from GMM estimation with a lagged dependent variable. Table A12 reports these results. We used the two-period lag of the dependent variable to instrument for the lagged dependent variable. The over-identification statistic ($\chi^2(106) = 114.8$ with p-value 0.26) fails to reject the null hypothesis, which suggests that our instruments are appropriately orthogonal.

In the tables of empirical results, ACQ denotes annual acquisitions, RDPER denotes R&D intensity, TA denotes total assets, RETSALE denotes returns to sales, DAT denotes debt ratio, and CFL denotes cash flow.

Finally, the end of this appendix gives further details about the GMM estimation procedure used in the paper and further description of the random-effects and "between" negative binomial models developed by Hausman et al. (1984)

TABLE A1: OLS results.

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º Ordinary    least squares regression    Weighting variable = ONE      º
º Dependent variable is ACQ       Mean =    0.27189, S.D. =      0.8615 º
º Model size: Observations =    1953, Parameters =   6, Deg.Fr. =  1947 º
º Residuals:  Sum of squares=    881.697     Std.Dev. =         0.67294 º
º Fit:        R-squared = 0.39136, Adjusted R-squared =         0.38979 º
º Model test: F[  5,   1947] =  250.38,    Prob value =         0.00000 º
º Diagnostic: Log-L =  -1994.6024, Restricted(á=0) Log-L =   -2479.4570 º
º             Amemiya Pr. Crt.=    0.454, Akaike Info. Crt.=      2.049 º
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼
```

Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	0.21942	0.21664E-01	10.129	0.00000	
RDPER	-0.14437	0.11484	-1.257	0.20870	0.9363E-01
TA	0.66165E-01	0.29365E-02	22.532	0.00000	1.226
RETSALE	0.23452	0.86269E-01	2.719	0.00656	-0.1309E-01
DAT	0.21095	0.54334	0.388	0.69783	0.2222E-01
CFL	-0.15441	0.39744E-01	-3.885	0.00010	0.1084

TABLE A2: Poisson results.

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ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
º Poisson Regression                          º
º Maximum Likelihood Estimates                º
º Dependent variable                 ACQ      º
º Number of observations            1953      º
º Iterations completed                 9      º
º Log likelihood function      -1222.648      º
º Restricted log likelihood    -1451.983      º
º Chi-squared                   458.6695      º
º Degrees of freedom                   5      º
º Significance level           0.0000000      º
º Chi- squared =  2951.86692  Rý_p=  0.4460   º
º G  - squared =  1705.61856  Rý_d=  0.2119   º
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼
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Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.0510	0.11042	-9.519	0.00000	
RDPER	-5.2553	0.95913	-5.479	0.00000	0.9363E-01
TA	0.15214E-01	0.20206E-02	7.530	0.00000	1.226
RETSALE	2.5678	0.54411	4.719	0.00000	-0.1309E-01
DAT	-3.6487	2.7823	-1.311	0.18973	0.2222E-01
CFL	0.15125	0.33205E-01	4.555	0.00001	0.1084

TABLE A3: Probit results where dependent variable is 1" if acquisition activity and 0" otherwise.

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              ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
              º Binomial Probit Model                        º
              º Maximum Likelihood Estimates                 º
              º Dependent variable                 ACQP      º
              º Number of observations             1953      º
              º Iterations completed                  6      º
              º Log likelihood function       -804.6909      º
              º Restricted log likelihood     -879.1409      º
              º Chi-squared                    148.9000      º
              º Degrees of freedom                    5      º
              º Significance level            0.0000000      º
              ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

 Variable  Coefficient   Standard Error  z=b/s.e. P[³Z³òz]   Mean of X
 ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
 Constant  -0.77912         0.84313E-01   -9.241   0.00000
 RDPER       -3.0740         0.68051       -4.517   0.00001  0.9363E-01
 TA         0.14691         0.31369E-01    4.683   0.00000   1.226
 RETSALE     2.0510         0.40691        5.040   0.00000 -0.1309E-01
 DAT        -2.4638          2.1191       -1.163   0.24496  0.2222E-01
 CFL       -0.75387         0.21750       -3.466   0.00053  0.1084
```

TABLE A4: Inclusion of alternative regressors: 1) Return on equity (ROE), 2) Return on investment (ROI), 3) Quick ratio (QR), 4) Current ratio (CR).

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              ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
              º Negative Binomial Regression                 º
              º Maximum Likelihood Estimates                 º
              º Dependent variable                  ACQ      º
              º Number of observations             1953      º
              º Iterations completed                 19      º
              º Log likelihood function       -1128.973      º
              º Restricted log likelihood     -1216.445      º
              º Chi-squared                    174.9437      º
              º Degrees of freedom                    1      º
              º Significance level            0.0000000      º
              ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

 Variable  Coefficient   Standard Error  z=b/s.e. P[³Z³òz]   Mean of X
 ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
 Constant   -1.0930         0.16862       -6.482   0.00000
 RDPER       -5.2091          1.2948       -4.023   0.00006  0.9363E-01
 TA         0.17433E-01     0.10431E-01    1.671   0.09466   1.226
 RETSALE     2.8531         0.67180        4.247   0.00002 -0.1309E-01
 ROE        0.11850E-02     0.16076E-02    0.737   0.46108  -1.554
 ROI       -0.22469E-03     0.84600E-03   -0.266   0.79055   4.291
 DAT        -5.3936          4.5606       -1.183   0.23695  0.2222E-01
 CFL        0.29675         0.12411        2.391   0.01680  0.1084
 QR         0.36713E-02     0.99507E-02    0.369   0.71217  0.5595
 CR        -0.12022E-03     0.90962E-03   -0.132   0.89485  -7.131
Alpha        2.1453         0.32032        6.697   0.00000
```

TABLE A5: Estimates from using a firm s sales as a proxy for size rather than total assets and defining RDPER as the ratio of R&D expenditures to sales.

```
ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
º Negative Binomial Regression                  º
º Maximum Likelihood Estimates                  º
º Dependent variable                  ACQ       º
º Number of observations             1953       º
º Iterations completed                 17       º
º Log likelihood function       -1121.251       º
º Restricted log likelihood     -1205.830       º
º Chi-squared                    169.1582       º
º Degrees of freedom                    1       º
º Significance level            0.0000000       º
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼
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Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.2585	0.14606	-8.616	0.00000	
RDPER	-5.2856	1.3588	-3.890	0.00010	0.7414E-01
SALES	162.01	27.228	5.950	0.00000	0.9773E-03
RETSALE	3.4996	0.62571	5.593	0.00000	-0.1309E-01
DAT	-2.8747	4.1944	-0.685	0.49312	0.2222E-01
CFL	-0.73547	0.21914	-3.356	0.00079	0.1084
Alpha	1.9322	0.30119	6.415	0.00000	

TABLE A6: Estimates of basic model when including a variable of total U.S. domestic acquisition activity (excluding the electronic and electrical equipment industries to avoid endogeneity) labeled as TOTACQ.

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ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
º Poisson Regression                            º
º Maximum Likelihood Estimates                  º
º Dependent variable                  ACQ       º
º Number of observations             1953       º
º Iterations completed                  9       º
º Log likelihood function       -1219.131       º
º Restricted log likelihood     -1451.983       º
º Chi-squared                    465.7035       º
º Degrees of freedom                    6       º
º Significance level            0.0000000       º
º Chi- squared =  2965.28321  Rý_p=  0.4435     º
º G  - squared =  1698.58455  Rý_d=  0.2152     º
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼
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Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.6609	0.25934	-6.404	0.00000	
RDPER	-5.2474	0.96165	-5.457	0.00000	0.9363E-01
TA	0.15542E-01	0.19954E-02	7.789	0.00000	1.226
RETSALE	2.5027	0.54257	4.613	0.00000	-0.1309E-01
DAT	-3.5372	2.7780	-1.273	0.20291	0.2222E-01
CFL	0.15189	0.32844E-01	4.625	0.00000	0.1084
TOTACQ	0.21566	0.82010E-01	2.630	0.00855	2.783

TABLE A7: Basic model with inclusion of time dummies.

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	ACQ
Number of observations	1953
Iterations completed	24
Log likelihood function	-1124.290
Restricted log likelihood	-1211.896
Chi-squared	175.2128
Degrees of freedom	1
Significance level	0.0000000

Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.5161	0.25306	-5.991	0.00000	
RDPER	-5.1632	1.2961	-3.984	0.00007	0.9363E-01
TA	0.15157E-01	0.10530E-01	1.439	0.15003	1.226
RETSALE	3.0750	0.70391	4.368	0.00001	-0.1309E-01
DATL	-4.4504	4.5540	-0.977	0.32844	0.2222E-01
CFLL2	0.32377	0.12840	2.522	0.01168	0.1084
Y86	0.68773	0.29957	2.296	0.02169	0.1113
Y87	0.52443	0.29011	1.808	0.07065	0.1111
Y88	0.32332	0.30075	1.075	0.28234	0.1111
Y89	0.33311	0.30311	1.099	0.27179	0.1117
Y90	0.23530	0.31071	0.757	0.44888	0.1111
Y91	0.34489E-01	0.31220	0.110	0.91204	0.1111
Y92	0.56328	0.28115	2.003	0.04512	0.1111
Y93	0.80319	0.28601	2.808	0.00498	0.1049
Alpha	2.0511	0.31934	6.423	0.00000	

TABLE A8: Basic model with inclusion of 4-digit Standard Industrial Classification (SIC) dummies.

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ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
º Negative Binomial Regression                  º
º Maximum Likelihood Estimates                  º
º Dependent variable                   ACQ      º
º Number of observations              1953      º
º Iterations completed                  22      º
º Log likelihood function        -1070.167      º
º Restricted log likelihood      -1106.622      º
º Chi-squared                     72.91039      º
º Degrees of freedom                     1      º
º Significance level             0.0000000      º
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼
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Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.6796	0.23550	-7.132	0.00000	
RDPER	-3.4654	1.3894	-2.494	0.01262	0.9363E-01
TA	0.13434E-01	0.81924E-02	1.640	0.10104	1.226
RETSALE	2.7872	0.67015	4.159	0.00003	-0.1309E-01
DAT	-6.0566	4.5592	-1.328	0.18404	0.2222E-01
CFL	0.22751E-01	0.95984E-01	0.237	0.81264	0.1084
S3570	1.5867	0.29304	5.414	0.00000	0.4147E-01
S3571	0.81321	0.29112	2.793	0.00522	0.4608E-01
S3572	0.29599	0.31883	0.928	0.35321	0.4608E-01
S3575	0.63887	0.42388	1.507	0.13176	0.1843E-01
S3576	-0.56593	0.43562	-1.299	0.19389	0.5991E-01
S3577	0.15442	0.29526	0.523	0.60098	0.8295E-01
S3578	0.16689	0.40952	0.408	0.68362	0.2765E-01
S3579	1.4449	0.34478	4.191	0.00003	0.1997E-01
S3600	2.4314	0.56929	4.271	0.00002	0.9217E-02
S3612	0.33070	1.0777	0.307	0.75896	0.4608E-02
S3613	-0.25567	0.92058	-0.278	0.78122	0.9217E-02
S3620	0.46109	0.46764	0.986	0.32414	0.1843E-01
S3621	1.4162	0.33546	4.222	0.00002	0.2304E-01
S3634	0.11640	1.0695	0.109	0.91334	0.4608E-02
S3640	0.32401	0.38232	0.847	0.39672	0.3226E-01
S3651	-0.82594	1.1168	-0.740	0.45958	0.9217E-02
S3661	0.54887	0.28639	1.916	0.05530	0.6912E-01
S3669	1.1020	0.26716	4.125	0.00004	0.4147E-01
S3670	0.91512E-01	0.46431	0.197	0.84375	0.2304E-01
S3674	0.26656	0.27757	0.960	0.33689	0.1060
S3678	0.97314	0.35772	2.720	0.00652	0.2304E-01
S3679	-0.66581	0.33642	-1.979	0.04780	0.9524E-01
S3690	0.66471	0.29850	2.227	0.02596	0.4147E-01
Alpha	1.1664	0.24960	4.673	0.00000	

TABLE A9: Estimates of basic model when we eliminate all sample firms that had no acquisitions during our sample period. This reduces the panel to 136 firms over 9 years for 1224 observations.

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	ACQ
Number of observations	1224
Iterations completed	13
Log likelihood function	-986.3008
Restricted log likelihood	-1036.984
Chi-squared	101.3668
Degrees of freedom	1
Significance level	0.0000000

Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-0.69593	0.16095	-4.324	0.00002	
RDPER	-4.0076	1.2556	-3.192	0.00141	0.7711E-01
TA	0.18630E-01	0.72426E-02	2.572	0.01010	1.929
RETSALE	2.3300	0.67759	3.439	0.00058	0.1820E-01
DAT	-6.0007	4.3818	-1.369	0.17086	0.2054E-01
CFL	0.13993	0.84906E-01	1.648	0.09935	0.1699
Alpha	1.1544	0.19836	5.820	0.00000	

TABLE A10: Estimates of basic model when eliminating observations for which R&D intensity is less than 2.5%. This reduces the number of observations to 1684.

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	ACQ
Number of observations	1684
Iterations completed	10
Log likelihood function	-899.0153
Restricted log likelihood	-967.5882
Chi-squared	137.1458
Degrees of freedom	1
Significance level	0.0000000

Variable	Coefficient	Standard Error	z=b/s.e.	P[³Z³òz]	Mean of X
Constant	-1.3242	0.22910	-5.780	0.00000	
RDPER	-3.8503	1.6428	-2.344	0.01909	0.1053
TA	0.79940E-01	0.22572E-01	3.542	0.00040	0.8900
RETSALE	3.7972	0.95070	3.994	0.00006	-0.1313E-01
DAT	-3.5086	5.5898	-0.628	0.53021	0.2080E-01
CFL	-0.16824	0.19614	-0.858	0.39103	0.9549E-01
Alpha	2.4058	0.40342	5.963	0.00000	

TABLE A11: Estimates of negative binomial between estimates when including the cash flow (CFL) variable.

Variable	Coefficient	Standard Error	z=b/s.e.
RDPER	-5.108	2.260	-2.260
TA	0.007	0.066	0.110
RETSALE	3.198	1.993	1.605
DAT	-0.902	7.590	-0.628
CFL	0.427	0.497	0.856
a	4.905	1.290	3.801
b	1.155	0.258	4.474

Log-likelihood: -389.11
Restricted Log-likelihood (coefficients restricted to be zero): -578.35
Likelihood-ratio Test (p-value): 378.48
(0.000)

TABLE A12: Estimates of GMM estimator which includes a lagged dependent variable.

Variable	Coefficient	Standard Error	z=b/s.e.
ACQ_L1	-0.006	0.001	-4.320
RDPER	-9.263	1.221	-7.582
TA	0.006	0.0002	27.683
RETSALE	1.013	0.536	1.889
DAT	-6.474	1.245	-5.120
CFL	-0.076	0.020	-3.780

Further details about the GMM estimation procedure used in the paper.

Following Wooldridge (1997), the GMM estimator is obtained by solving

$$\min_{\beta} \left[\sum_{i=1}^{N} \hat{W}_i^{\prime} r_i(\beta)\right]^{\prime} \hat{\Omega}^{-1} \left[\sum_{i=1}^{N} \hat{W}_i^{\prime} r_i(\beta)\right], \qquad \textbf{(A1)}$$

where β is a vector of parameters, r_i (β) is a (T-1)x1 vector, (r_{i1}(β) , . . . , $r_{i,\,T\text{-}1}$ (β))' , and $\hat{W}_i$ is a matrix of instruments defined as

$$\begin{bmatrix} \hat{w}_{i1} & 0 & 0 & . & . & . & 0 & 0 \\ 0 & \hat{w}_{i2} & 0 & . & . & . & 0 & 0 \\ & & & & . & & & \\ & & & & . & & & \\ 0 & 0 & 0 & & & & 0 & \hat{w}_{i,T-1} \end{bmatrix}$$

where $\hat{w}_{it}$ is a 1xL vector of instruments for each t=1, . . . T-1. In addition, given an $\sqrt{N}$ - consistent estimator, $\hat{\beta}$, one can obtain

$$\hat{\Omega} \equiv N^{-1} \sum_{i=1}^{N} W_i(\hat{\beta})^{\prime} r_i(\hat{\beta}) r_i(\hat{\beta})^{\prime} W_i(\hat{\beta}) \qquad \textbf{(A2)}$$

From this set up a one-step estimator, which is first-order equivalent to the GMM estimator, takes the form

$$\beta_{GMM} = \hat{\beta} + (\hat{R}^{\prime} \hat{\Omega}^{-1} \hat{R})^{-1} N^{-1} \sum_{i=1}^{N} \hat{s}_i \qquad \textbf{(A3)}$$

where $\hat{R} \equiv N^{-1} \sum_{i=1}^{N} w_i(\hat{\beta})^{\prime} \nabla_{\beta} r_i(\hat{\beta})$, $\nabla_{\beta} r_i(\hat{\beta})$ is a matrix of derivatives of $r_i(\beta)$ with respect to β, and $\hat{s}_i = \hat{R}^{\prime} \hat{\Omega}^{-1} \hat{w}_i^{\prime} \hat{r}_i$. The asymptotic covariance matrix of β_{GMM} is estimated by $N^{-1}(\tilde{R}^{\prime} \tilde{\Omega}^{-1} \tilde{R})^{-1}$, where $\tilde{R}$ and $\tilde{\Omega}$ are defined as above, except with parameter vector β_{GMM} in place of $\hat{\beta}$.

Further description of the random-effects and between negative binomial models developed by Hausman et al. (1984)

To develop a random effects negative binomial model, Hausman et al. (1984) begin with a standard Poisson distribution and assume that the Poisson parameter, λ_{it}, follows a gamma distribution with shape parameters, (γ,δ). As is standard, we can parameterize γ to be an exponential function of the independent variables, X_{it}, such that $\gamma_{it} = \exp(X_{it}\beta)$. Then, to introduce variation across industries, they assume that each industry (i) has its own δ_i, which are randomly distributed across the (i) industries. To accomplish this, Hausman et al. assume that the ratio $\delta_i/(1+\delta_i)$ is distributed as a beta random variable with shape parameters (a,b). Using this beta density they derive the joint probability of an industry's acquisitions over the panel years to be

$$\text{pr}(y_{i1},...,y_{iT} \mid X_{i1},...,X_{iT}) = \frac{\Gamma(a+b)\Gamma(a+\Sigma_t\gamma_{it})\Gamma(b+\Sigma_t y_{it})}{\Gamma(a)\Gamma(b)\Gamma(a+b+\Sigma_t\gamma_{it}+\Sigma_t y_{it})}\left(\prod_t \frac{\Gamma(\gamma_{it}+y_{it})}{\Gamma(\gamma_{it})\Gamma(y_{it}+1)}\right) \quad \textbf{(B1)}$$

where y_{it} denot es the dependent variable. The random effects negative binomial model thus has two “shape” parameters, a and b, to estimate, in addition to our coefficient vector, β. The log likelihood function follows directly from equation B1 and can be estimated using standard maximum likelihood techniques.

The “between” estimator developed by Hausman et al. starts with the assumption that the pooled observations follow a negative binomial model. Rather than focus on means of the variables, as in the linear context, Hausman et al. next construct the marginal probability of the sum of the acquisitions for a firm over the time period of the sample conditioned on the independent variables. The sum of a negative binomial distribution with shape parameters (γ,δ) can be shown to follow a negative binomial distribution with shape parameters $(\Sigma_t y_{it}, \delta)$. Assuming the ratio $\delta_i/(1+\delta_i)$ is distributed as a beta random variable with shape parameters (a,b), the “between” estimator takes a hypergeometric form,

$$\text{pr}(\Sigma_t y_{it} \mid X_{i1},...,X_{iT}) = \frac{\Gamma(\Sigma_t\gamma_{it}+\Sigma_t y_{it})\Gamma(a+b)\Gamma(a+\Sigma_t\gamma_{it})\Gamma(b+\Sigma_t y_{it})}{\Gamma(\Sigma_t\gamma_{it})\Gamma(\Sigma_t y_{it}+1)\Gamma(a)\Gamma(b)\Gamma(a+b+\Sigma_t\gamma_{it}+\Sigma_t y_{it})}. \quad \textbf{(B2)}$$

A log likelihood function can be constructed from equation B2 and estimated using standard maximum likelihood techniques.