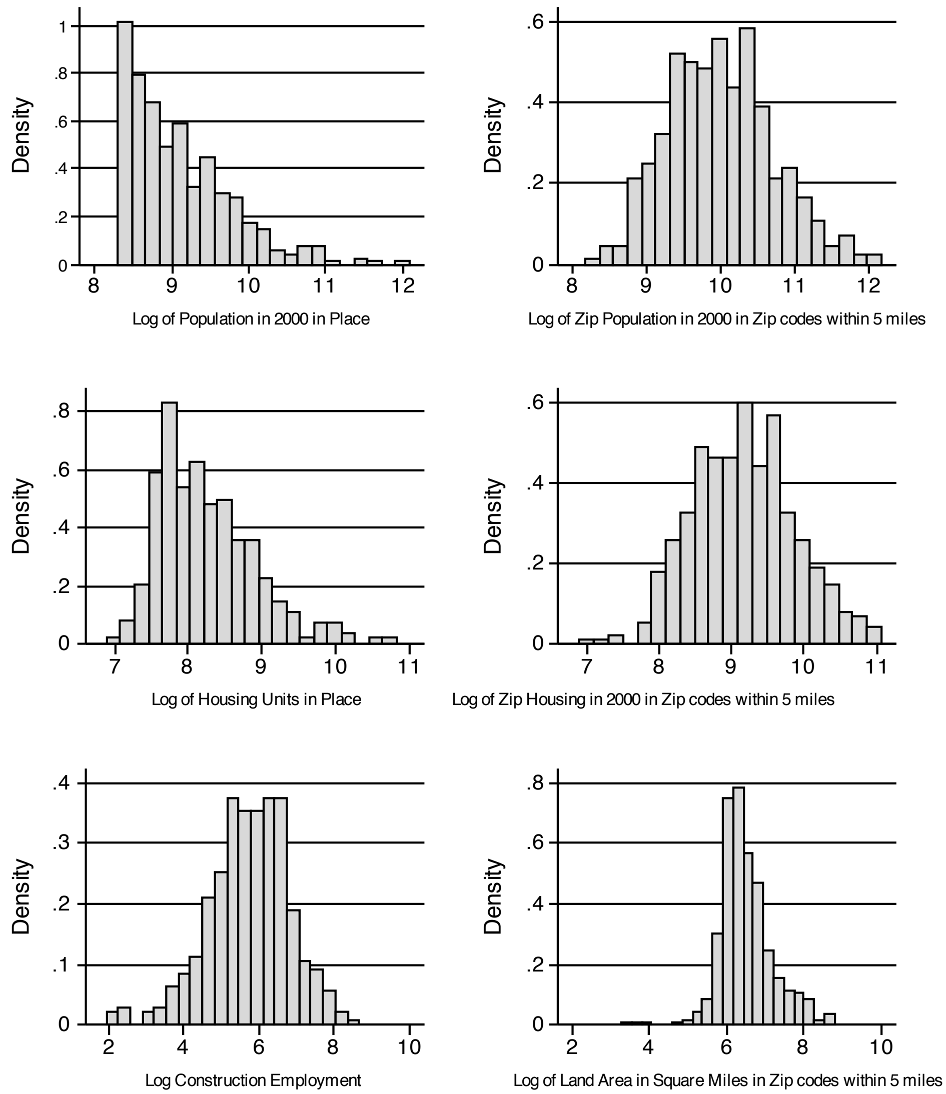
Web Appendix for "Mergers and Sunk Costs: An application to the ready-mix concrete industry"

Allan Collard-Wexler
NYU Stern and NBER

January 7, 2014

1 Additional Tables and Figures



Note: Place refers to the isolated town itself, while Zip refers to the zip codes within a 5 mile distance of the town.

Figure 1: Distribution of Town Size

Dependent Variable: Number of Plants in a Market	I	II	III	IV	V	VI
Market Selection						
All	X					
Zip area below 850 square miles		X				X
No Highway			X			
More than 70% population of zip codes (within 5 miles) in place				X		X
No cities of 2000 people within 40 miles					X	
Construction Employment	0.38***	0.48***	0.39***	0.30	-0.09	1.51***
in Thousands	(0.09)	(0.12)	(0.11)	(0.21)	(0.15)	(0.27)
Entry Term γ_1	-1.46***	-1.43***	-1.45***	-1.62***	-1.63***	-1.74***
	(0.06)	(0.08)	(0.08)	(0.13)	(0.14)	(0.17)
First Competitor	-1.04***	-1.03***	-1.06***	-1.15***	-1.22***	-1.24***
	(0.06)	(0.07)	(0.07)	(0.13)	(0.21)	(0.15)
Second Competitor	-0.87***	-0.94***	-0.89***	-1.20***	-0.96***	-1.63***
	(0.07)	(0.09)	(0.09)	(0.18)	(0.21)	(0.20)
Third Competitor	-0.82***	-0.95***	-0.84***	-0.73**		-1.08*
	(0.10)	(0.14)	(0.13)	(0.27)		(0.45)
Fourth Competitor	-0.93***	-1.05**		-0.36		-0.42*
	(0.21)	(0.33)		(0.21)		(0.19)
More than four Competitors	-0.72***	-0.59***	-1.65***	-0.59***	-1.12***	-1.21***
	(0.10)	(0.09)	(0.38)	(0.16)	(0.22)	(0.23)
Gap Entry-Continuation γ_2	3.56***	3.52***	3.60***	3.85***	4.02***	3.84***
	(0.07)	(0.07)	(0.07)	(0.14)	(0.19)	(0.16)
Log-Likelihood	-1814.1	-1339.1	-1269.8	-439.2	-284.1	-272.6
Observations	5321	3814	3821	1668	1220	1056
Markets	445	319	320	139	102	88

Table 1: SBR Model Estimates Market Definition

Dependent Variable Number of Plants in a Market	I	II	III	IV	V	VI	VII
Construction Employment	0.379***					0.329**	0.143
(in 000's)	(0.09)					(0.11)	(0.11)
Housing units in Place		0.026*					
(in 000's)		(0.01)					
Housing units in zip codes			0.027***				-0.002
within 5 miles (in 000's)			(0.01)				(0.03)
Population in Place				0.010**		0.004	
(in 000's)				(0.00)		(0.01)	
Population in zip codes					0.011***		0.009
within 5 miles (in 000's)					(0.00)		(0.01)
Land Area of Place						-0.191	
(in 000's)						(0.16)	
Entry Term γ_1	-1.464***	-1.415***	-1.617***	-1.408***	-1.592***	-1.481***	-1.587***
	(0.06)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)	(0.08)
First Competitor	-1.045***	-1.012***	-1.049***	-1.013***	-1.046***	-1.045***	-1.054***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Second Competitor	-0.872***	-0.841***	-0.898***	-0.844***	-0.898***	-0.872***	-0.899***
	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Third Competitor	-0.820***	-0.800***	-0.841***	-0.807***	-0.850***	-0.828***	-0.852***
	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.11)
Fourth Competitor	-0.929***	-0.884***	-1.003***	-0.898***	-1.028***	-0.942***	-1.026***
	(0.21)	(0.20)	(0.21)	(0.20)	(0.21)	(0.20)	(0.19)
More than 4 Competitors	-0.723***	-0.710***	-0.831***	-0.745***	-0.892***	-0.753***	-0.874***
	(0.10)	(0.12)	(0.12)	(0.14)	(0.12)	(0.12)	(0.14)
Gap Entry-Continuation γ_2	3.555***	3.545***	3.569***	3.549***	3.572***	3.558***	3.571***
	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
χ^2	17.79	5.44	21.83	7.58	24.04	19.83	23.67
Log-Likelihood	-1814.1	-1841.3	-1798.2	-1837.8	-1796.9	-1811.2	-1793.5
Observations	5321	5321	5321	5321	5321	5321	5321
Markets	445	445	445	445	445	445	445

Standard Errors Clustered by market.

Table 2: SBR Model Estimates: Different Measures of Demand

Dependent Variable: Number of Plants in a Market	No Effect I	II	III	Random Effect IV	V	VI
Log Construction Employment	0.29	0.28	0.27	0.59	0.71	0.70
	(0.05)	(0.04)	(0.04)	(0.01)	(0.01)	(0.01)
1 competitor	-1.08	-1.14	-1.12	-2.79	-3.04	-3.07
	(0.08)	(0.06)	(0.07)	(0.01)	(0.02)	(0.02)
2 competitor	-0.89	-0.74	-0.91	-2.41	-1.26	-1.37
	(0.06)	(0.08)	(0.08)	(0.02)	(0.02)	(0.02)
3 competitor	-0.82	-1.09	-0.82	-1.91	-1.66	-1.13
	(0.10)	(0.16)	(0.11)	(0.02)	(0.02)	(0.05)
4 competitor	-0.91	-1.09	-1.87	-1.91	-1.44	-1.41
	(0.22)	(0.27)	(0.53)	(0.08)	(0.04)	(0.04)
Competitors above 4	-0.70	-0.79	-0.98	-1.21	-0.92	-0.88
	(0.10)	(0.12)	(0.17)	(0.06)	(0.04)	(0.04)
Entry Parameter γ^E	-2.95	-2.83	-2.82	-4.51	-5.38	-5.35
	(0.26)	(0.25)	(0.82)	(0.19)	(0.15)	(0.15)
σ_μ				2.44	2.59	2.60
				(0.01)	(0.01)	(0.01)
Sunk Cost Parameter γ_0^S	3.56	3.45	3.46	4.63	5.20	5.23
	(0.07)	(0.07)	(0.09)	(0.22)	(0.02)	(0.02)
Sunk Cost Parameter γ_1^S	-	0.80	0.37	-	-1.82	-1.66
More than 1 Firm$*$	-	(0.09)	(0.10)	-	(0.03)	(0.04)
Sunk Cost Parameter γ_2^S	-	-	1.53	-	-	-0.73
More than 2 Firm$*$	-	-	(0.25)	-	-	(0.07)
Observations	5321	5321	5321	5245	5245	5245
Markets	445	445	441	445	449	300
Log-Likelihood	-1791	-1746	-1712	-1306	-1267	-1264

Standard Errors Clustered by Market for columns I, II and III. $*$ Note that $\gamma^S = \gamma_0^S + \gamma_1^S 1(N_{mt} > 1) + \gamma_2^S 1(N_{mt} > 2)$.

Table 3: Non-Constant Gap between entry and continuation thresholds estimates

2 Stationary and a Closed Form Solution for Entry and Exit Thresholds

Suppose that demand is constant over time. In this case the value function is just the net present value of period variable profits minus fixed costs f:

$$\begin{aligned} V(D,N) &= \sum_{t=0}^{\infty} \beta^t (\pi^V(D,N) - f) \\ &= \frac{Dg(N)}{1-\beta} - \frac{f}{1-\beta} \end{aligned} \tag{1}$$

When demand varies over time, I can rewrite the value in terms of deviations from the stationary case:

$$\begin{aligned} (1-\beta)V(D,N) = {} & Dg(N) - f \\ & + \underbrace{\left(\sum_{t=0}^{\infty} \frac{\beta^t}{1-\beta} D_t g(N_t) - Dg(N)\right)}_{\text{Deviation of variable profits}} \\ & - \underbrace{\left(\sum_{t=0}^{\infty} \frac{\beta^t}{1-\beta} f a_t - f\right)}_{\text{Deviation of fixed costs}} \end{aligned} \tag{2}$$

As long as the market does not vary too much over time, the errors from the stationary approximation in equation (1) will be small. When I simulate the demand process, I find that the correlation between demand today D_{mt} and the net present value of demand over the next 50 years is 0.82, thus fairly high. As well, the correlation between the number of firms today N_{mt} and the net present value of the number of firms in the market is 0.91, so again a fairly high number. Note that while stationarity is important to the interpretation of the value function, for the actual estimation and counterfactual experiment I do not need to know the functional form of the value function. I just need to be able to approximate it in a "reduced-form". [1]

The entry and exit thresholds in equation (**??**) can be rewritten using the multiplicative separability of period profits, and the stationary approximation:

$$\begin{aligned} \frac{1}{1-\beta}\epsilon_{mt} D_{mt} g(N_{mt}) &\geq \frac{1}{1-\beta} f + \phi + 1(N_{mt} > N_{mt-1})\gamma \\ \frac{1}{1-\beta}\epsilon_{mt} D_{mt} g(N_{mt}+1) &< \frac{1}{1-\beta} f + \phi + 1(N_{mt} \geq N_{mt-1})\gamma \end{aligned} \tag{4}$$

[1] Specifically, one could interpret this exercise as estimating the value function using a sieve maximum likelihood:

$$(1-\beta)V(D,N) \approx c_1 Dg(N) + \sum_k c_k \phi^k(D,N) \tag{3}$$

As long as the number of terms is large enough to approximate the value function well, I will still obtain correct policy counterfactuals, even thought the interpretation of the coefficients is lost.

As long as $g(N)$ is positive, I can express $g(N)$ as $g(N) = e^{h(1)}e^{h(2)} \cdots e^{h(N)}$. Rearranging, taking logs, and combining terms I obtain:

$$\begin{aligned}
\varepsilon_{mt} &\geq -\beta_1 \log(D_{mt}) - \sum_{k=1}^{N_{mt}} h(k) + \gamma^E + \gamma^S 1(N_{mt} > N_{mt-1}) \\
\varepsilon_{mt} &< -\beta_1 \log(D_{mt}) - \sum_{k=1}^{N_{mt}+1} h(k) + \gamma^E + \gamma^S 1(N_{mt} > N_{mt-1})
\end{aligned} \tag{5}$$

where $\gamma^E = \log(\frac{1}{1-\beta} f + \phi)$ and $\gamma^S = \log(\frac{1}{1-\beta} f + \phi + \gamma) - \log(\frac{1}{1-\beta} f + \phi)$, and $\varepsilon = \log(\epsilon)$.

3 Monte-Carlo Study of the Fixed-Effects Ordered Probit

There are a limited number of econometric models which allow for fixed-effect estimation, most notably: 1- linear model where fixed-effects can be differenced out, 2- the conditional logit model of McFadden and 3- moment inequality models such as Pakes, Porter, Ho, and Ishii (2006). The Pakes, Porter, Ho, and Ishii (2006) model seems to provide a good solution for differencing out the fixed effects. In particular, if we take the difference between profits in a market at times t and τ:

$$\xi = \pi(D_{mt}, N_{mt}) - \pi(D_{m\tau}, N_{m\tau} + 1) \geq 0$$

this difference will be positive and the market level fixed effect will be differenced out. However, this moment inequality is conditional on having at least one firm per market, a condition which is frequently violated in the data. Dropping these markets will generate an error ξ which is no longer mean zero unless we focus our attention on markets where the zero firm count problem is never an issue.

In most non-linear model, however, fixed-effects need to be estimated individually. The variance in the estimates of these fixed effects or incidental parameters in the terminology of Neyman and Scott (1948) and Heckman (1981) contaminates the remaining coefficients, and has been shown to generate bias in these coefficients. Indeed, Greene (2004) p.126 summarizes the existing literature as:

> The now standard "result" is that the fixed-effects estimator is inconsistent and substantially biased away from zero when group sizes are small (e.g., by 100% when $T = 2$)

Thus the fixed-effect estimator in a non-linear model such as the ordered probit type model used in this paper, can be biased for small panel lengths T, even if the number of markets M is quite large. Yet, it is an open question of how quickly the bias of the fixed-effect ordered probit model shrinks as T increases. For instance, Greene (2001) discusses the bias of estimating non-linear models with fixed effects (typically with maximum likelihood), and Greene (2004) finds relatively small bias in a fixed-effect tobit model.

The purpose of this section is to look at the finite sample bias of the ordered-probit estimator used in this paper using a Monte-Carlo study. I find that the bias of the fixed-effect estimator is relatively small, i.e. less than 20% of the coefficients, which is within the standard errors. Moreover, the bias attenuate the parameter estimates relative to their true values.

Algorithm 1 *Monte-Carlo for Fixed-Effect Ordered Probit*

For $k = 1, \cdots, 1\,000$:

1. Draw $\epsilon_t^k \sim \log(\mathcal{N}(0,1))$.

2. Predict number of firms i.e., N_t^k that satisfies:

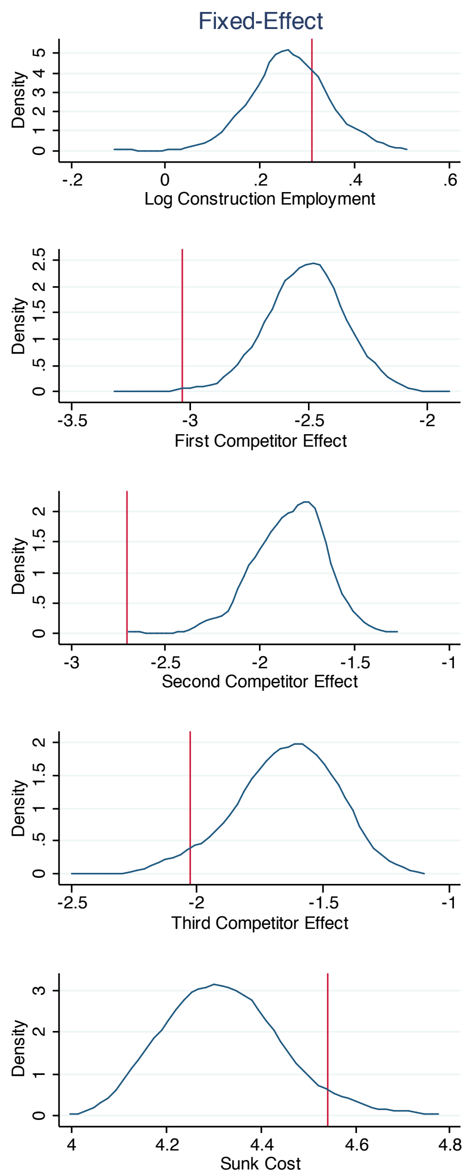
$$V^{\theta^0}(\epsilon_t^k D_t, N_t^k) \geq \phi + 1(N_t^k > N_{t-1}) \underbrace{(\psi - \phi)}_{\gamma}$$

$$V^{\theta^0}(\epsilon_t^k D_t, N_{t-1}^k) < \phi + 1(N_t^k \geq N_{t-1}) \underbrace{(\psi - \phi)}_{\gamma}$$

   where θ^0 are the estimates from column VI of Table **??** on page **??**, including all market level fixed effects. Note that D_t and N_{t-1} refer to demand and lagged number of firms in the data.

3. Use data set $X^k = \{N_t^k, N_{t-1}, D_t\}$ to estimate parameters $\hat{\theta}_{FE}^k$ and $\hat{\theta}_{NE}^k$ (no fixed-effects).

Figure 2 shows the results of Monte-Carlo exercise. The fixed-effect coefficients are somewhat biased, on the order of up to 20% for certain competition parameters. This bias is in the direction of attenuating the parameters so the large increase in the size of the competition parameters is an underestimate. Moreover, this bias is well within the confidence intervals, so our interpretation of the parameters is not modified very much.



Note: Line is true value of the parameter. Kernel Density from 1000 Monte-Carlo replications using estimates from fixed-effect sunk-cost model, i.e. column VI of Table **??** on page **??**.

Figure 2: Monte-Carlo Estimation of Sunk Cost Entry Model with market level fixed effects.

4 Initial Conditions Problem

An initial conditions problem (Heckman, 1981) may arise when using the random effect estimates of the SBR model. In Table 4, I investigate the robustness of the random effect results to a more flexible specification of the distribution of μ_m given by $\mu_m \sim \mathcal{N}(\alpha Z_{0m}, \sigma_\mu)$ where Z_{0m} are variables at the initial state (i.e. at time 0). Column I shows the random effects estimates, and Columns II, III and IV allow the initial condition to depend on log construction employment, the number of plants, and both. The main results of the SBR model are unchanged when including additional initial conditions controls, in particular for the competition coefficients, and the sunk cost parameters which determine the size of the stasis zone. However, the effect of construction employment falls, which is to be expected as these initial controls allow μ to be correlated with demand, and this loads the cross-sectional correlation between plants and demand onto μ. As well, the variance of μ, σ_μ, falls when the number of plants in the first period is added, as the number of firms in the initial period is a good predictor of the market unobservable μ.

Dependent Variable Number of Plants in a Market	I	II	III	IV
Log Construction Employment	0.58	0.28	0.18	0.20
	(0.00)	(0.00)	(0.02)	(0.02)
1 competitor	-2.79	-2.72	-2.80	-2.72
	(0.01)	(0.01)	(0.01)	(0.01)
2 competitor	-2.41	-2.43	-2.42	-2.43
	(0.02)	(0.02)	(0.02)	(0.02)
3 competitor	-1.91	-1.89	-1.89	-1.89
	(0.02)	(0.02)	(0.02)	(0.02)
4 competitor	-1.91	-2.01	-1.92	-2.01
	(0.08)	(0.08)	(0.08)	(0.08)
Competitors above 4	-1.21	-1.31	-1.28	-1.31
	(0.06)	(0.07)	(0.06)	(0.07)
Entry Parameter γ^E	-4.52	-4.23	-5.42	-4.31
	(0.19)	(0.14)	(0.33)	(0.15)
Sunk Cost Parameter γ^S	4.63	4.56	4.62	4.56
	(0.01)	(0.01)	(0.01)	(0.01)
σ_μ	2.44	1.53	2.46	1.53
	(0.01)	(0.01)	(0.01)	(0.01)
Initial Conditions μ				
Number of Plants at $t = 0$		1.69		1.68
		(0.01)		(0.01)
Log Construction Employment at $t = 0$			0.58	0.09
			(0.03)	(0.02)
Observations	5388	5388	5388	5388
Markets	449	449	449	449
Log Likelihood	-1306	-1107	-1298	-1107

Standard errors computed assuming no serial correlation across markets.

Table 4: Sunk-Cost Bresnahan-Reiss Model Estimates with Initial Conditions Controls

References

Greene, W. (2001): "Estimating econometric models with fixed effects," *Stern School of Business, Department of Economics, Working Paper*, pp. 01–06.

——— (2004): "Fixed effects and bias due to the incidental parameters problem in the Tobit model," *Econometric Reviews*, 23(2), 125–147.

Heckman, J. J. (1981): "The incidental parameters problem and the problem of initial conditions in estimating a discrete time-discrete data stochastic process," in *Structural Analysis of Discrete Data with Econometric Applications*, pp. 179–197. MIT Press.

Neyman, J., and E. L. Scott (1948): "Consistent Estimates Based on Partially Consistent Observations," *Econometrica*, 16(1), 1–32.

Pakes, A., J. Porter, K. Ho, and J. Ishii (2006): "Moment inequalities and their application," *Unpublished Manuscript*.