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Electronic Companion—"Drivers of Finished-Goods Inventory in the U.S. Automobile Industry" by Gérard P. Cachon and Marcelo Olivares, *Management Science*, DOI 10.1287/mnsc.1090.1095.

# ONLINE APPENDIX

**Estimation of the Cost Markups**

We used the methodology described in Berry et. al.(1995) (hereon BLP) to estimate markups for each model on each year. We briefly outline this methodology and refer interested readers to the original articles for details.

This methodology forms part of a broad class of econometric models known as structural estimation. Assuming a theoretical model of decision making, this approach attempts to impute the parameters of the decision model that best fit the observed data. In our application, following BLP, we assume the U.S. automotive industry is an oligopoly where auto prices are determined through Bertrand/Nash equilibrium in a differentiated product market. If we knew the complete specification of demand for automobiles and the marginal costs of manufacturing each car, then we could compute the equilibrium sales and prices (and therefore the markups) for each model. Structural estimation follows the reverse approach. Given the equilibrium prices and market shares observed in the data, we estimate the costs and demand parameters that are consistent with this equilibrium under the maintained behavioral assumption of the agents in the market.

Let $p_j$ and $c_j$ be the price and (constant) marginal cost of model $j$ in a specific market. Let $J_f$ be the set of models offered by firm $f$. Demand is defined by the function $D_j(\vec{p}, \vec{x})$ which specifies the total demand of product $j$ as a function of the vector of prices $\vec{p}$ and the vector of characteristics $\vec{x}$ of all the products offered in the market. The profit function for firm $f$ is given by:

$$\pi_f = \sum_{j \in J_f} (p_j - c_j) D_j(\vec{p}, \vec{x}) - \text{Fixed Costs}_j$$

Denote by $M$ the total market size and $s_j(\vec{p}, \vec{x}) = D_j(\vec{p}, \vec{x})/M$ the market share of model $j$. Under Nash equilibrium in prices, the equilibrium price vector $\vec{p}^*$ and market share vector $\vec{s}^*$ must satisfy:

$$\vec{s}^* + \sum_{r \in J_f} (p_r^* - c_r) \times \frac{\partial s_r(\vec{p}^*, \vec{x})}{\partial p_j} = 0 \tag{1}$$

for all models $j$ in the market. Denote the equilibrium markup of model $j$ by $b_j^* = p_j^* - c_j$. Let $b^*$ be the stacked vector of these markups and define the matrix $\Delta$ of price substitutions by $\Delta_{jr} = \partial s_r/\partial pr$ if product $j$ and $r$ are produced by the same firm, and $\Delta_{jr} = 0$ otherwise.

Equation (1) can be rewritten in matrix form as:

$$b^* = \Delta^{-1} s^* \tag{2}$$

where $b$ and $s$ are the stacked vectors of markups and market shares, respectively.

Equation (2) specifies the markups as a function of the price substitutions and the equilibrium market shares. Therefore, if we knew $\Delta$, we could compute the markups using the observed market shares, assuming these quantities were reached through the Nash equilibrium in prices described above. The matrix $\Delta$ is defined by: (i) the set of models produced by each firm, which we observe in the data; and (ii) the price substitutions $\partial s_j / \partial p_r$, which we do not observe directly. Therefore, in order to compute the markups, we need to estimate demand in the auto industry. As summarized by Nevo (2000), researchers face two main difficulties in estimating demand for differentiated products: (i) the number of substitutions to be estimated increases in the square of the number of products; and (ii) prices are endogenous and tend to be correlated with unobserved product quality.

To overcome the first problem, BLP uses a random-coefficient multinomial logit which incorporates unobserved heterogeneity in consumer tastes for product attributes, allowing for flexible substitution patterns in the data. To overcome the second problem, BLP uses instrumental variables. Valid instruments for price are cost shifters and the characteristics of *other products* available in the market.

We estimated demand using data from 1996 to 2004. We defined the U.S. market sales for a given year as our market, giving a total of 9 markets. As in BLP, we used the number of households in the U.S. as our size of the market. We included all car models, all SUVs and CUVs and minivans. We excluded pickups and full size vans from the analysis. In addition to prices, we included random coefficients for the following product characteristics: (i) car size (the product of the length and width of the vehicle); (ii) a measure of acceleration (horsepower divided by weight); (iii) Miles per dollar of gasoline (based on EPA Miles per gallon measures and the average price of gasoline during the year); (iv) a measure of security (the sum of the indicators on whether the base model has airbags and Automatic Break System); and (v) indicators on market segment (whether the auto was classified in the following non-overlapping segments: cars, sport cars, SUV and minivan). We let the price coefficient interact with personal income, which was drawn from a lognormal distribution. The median income varies across years and was obtained from CPS. All dollar values are normalized to

1982-83 dollars using the CPI. We included non-random coefficients in the demand side to control for brand (Ford, GM, Chrysler, Honda, Toyota, Nissan, other European brands and other Asian brands). We added two measures based on the ratings from Consumer Reports: a dummy to indicate whether the model was recommended and a dummy on whether the product was rated above average. On the supply side, we included all the product characteristics (without the brand dummies nor the Consumer Report variables) plus a trend. We added variables indicating the percentage of production coming from plants in the U.S., Canada and Mexico and from overseas[1]. We did not include wages and exchange rates in the cost side as in BLP.

Our implementation was based on the source code provided by Nevo (2000). We modified the source code to include the supply equation into the estimation. We also added routines to compute the optimal instruments described in BLP. Both the supply side and the use of optimal instruments improved significantly the precision of our coefficient estimates. Overall, our results are consistent with those obtained in BLP, especially in the estimation of the price elasticities and cross-substitutions.

Table A3 provides a sample of the estimated markups for different years. The markups look reasonable both in absolute magnitude and in relative comparison across models. "Mainstream" cars, such as the Honda Accord, the Toyota Camry and the Ford Taurus tend to have smaller markups, while Sport models (Porsche 911), SUV's (Chevy Suburban) and expensive luxury vehicles (Mercedes E Class and Jaguar XJ6) tend to have larger markups. Even though the markups are increasing with the price of a vehicle, markups and cost markups are not proportional. Note also that some models exhibit unreasonable markups. For example, the Mini Cooper exhibits very low markups because we do not capture specific attributes of these exclusive models in our product characteristics. The sports car segment also exhibits particularly low cost markup. We also observe that there is some variation in the markups across time within a model, which is useful to identify the effect of this variable on inventory performance. Table A4 shows the price semi-elasticities, defined as the percent change in market share after a $1000 price change, for a sample of models. The table shows that

[1] We further classified imports into Europe, Japan and other Asian countries based on their make. For models that have both domestic and imported production, we aproximated the percentage of imports by the difference in annual sales and domestic production.

price changes tend to have the largest effect on products in the same segment[2]. We also note that the magnitude of the semi-elasticities differ across segments, which suggests that the propensity to substitute differs across vehicle types. This provides further support for controlling for market segment in our econometric model.

To validate our cost markup estimates, we calculated the gross profit per vehicle for each make implied by the model markups and compared it to the dealership gross profit per vehicle published by Automotive News. If dealerships get a fixed proportion of the supply chain profits and we measure the markups precisely, this two measures should be perfectly correlated. The correlation between the two measures is 0.8 (approximately). A regression with dealership profit as the dependent variable and the calculated markups and an intercept as covariates gives a coefficient of determination ($R^2$) of 0.7, that is, 70% of the variation in dealership gross profits can be explained by our estimated markups.

[2] If the choice model were a standard Multi-nomial logit (MNL) model, all the rows in this table would then be identical. Therefore, including segment indicators as random coefficients helps to overcome the restrictions of the MNL.

## ADDITIONAL TABLES

| Manufacturer | Total Domestic | No. Plants Excluded | Excluded Plants | Products in excluded plants |
|---|---|---|---|---|
| *AM General* | 2 | 2 | All | |
| *AutoAlliance* | 1 | 0 | | |
| *BMW* | 2 | 2 | All | |
| *CAMI* | 1 | 0 | | |
| *Chrysler Corp.* | 16 | 1 | Conner | Dodge Viper, Prowler |
| *Ford N.A. Mfg.* | 23 | 0 | | |
| *General Motors* | 34 | 0 | | |
| *Honda* | 6 | 1 | Lincoln | Odyssey(*), Pilot(*) |
| *Mercedes Benz* | 2 | 2 | All | |
| *Mitsubishi* | 1 | 0 | | |
| *Nissan* | 4 | 1 | Canton | Infiniti QX56, Altima(*), Armada, Quest, Titan |
| *NUMMI* | 2 | 0 | | |
| *Subaru* | 1 | 1 | | |
| *Toyota* | 4 | 2 | Princeton, Tijuana | Sequoia, Sienna(*), Tundra, Tacoma |
| *Volkswagen* | 1 | 1 | All | |
| *Volvo* | 1 | 1 | All | |

*(*) Models were also produced at other plants included in our dataset.*

Table A1 - Detail of domestic plants of each manufacturer which *do not* have data available in the Harbour Report.

| Manufacturer | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| *AM General* | | | | | 0% | 0% | 0% | 0% | 0% | 0% |
| *AutoAlliance* | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 87% |
| *BMW* | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *CAMI* | 58% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 94% |
| *Chrysler Corp.* | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 94% | 99% |
| *Ford N.A. Mfg.* | 100% | 98% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| *General Motors* | 97% | 98% | 98% | 99% | 100% | 96% | 96% | 95% | 95% | 97% |
| *Honda* | 81% | 79% | 79% | 71% | 66% | 64% | 73% | 70% | 67% | 72% |
| *Mercedes Benz* | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *Mitsubishi* | 0% | 0% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 66% |
| *Nissan* | 75% | 70% | 62% | 64% | 55% | 50% | 55% | 55% | 45% | 57% |
| *NUMMI* | 100% | 100% | 100% | 100% | 100% | 100% | 98% | 100% | 100% | 100% |
| *Subaru* | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *Toyota* | 100% | 100% | 100% | 92% | 84% | 78% | 79% | 68% | 61% | 82% |
| *Volkswagen* | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *Volvo* | 0% | 0% | 0% | | | | | | | 0% |
| *TOTAL* | 91% | 92% | 92% | 92% | 91% | 88% | 89% | 87% | 85% | 90% |

Table A2 – Percentage of total domestic production covered by our sample, by manufacturer by year.

| Model | Avg Markup | Avg CostMk | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|
| ACCENT | 3.964 | 62% | 65% | 66% | 71% | 55% |
| NEON (DODGE) | 4.666 | 54% | 56% | 57% | 58% | 56% |
| SENTRA | 4.930 | 58% | 57% | 58% | 60% | 58% |
| CIVIC | 5.079 | 63% | 63% | 64% | 67% | 65% |
| FOCUS | 5.433 | 68% | 75% | 63% | 66% | 63% |
| ESCORT | 5.503 | 68% | 61% | 74% | | |
| MINI COOPER | 6.118 | 54% | | 55% | 53% | 55% |
| GOLF | 6.219 | 61% | 62% | 60% | 62% | 61% |
| RAV4 | 7.174 | 65% | 63% | 61% | 63% | 55% |
| CAMARO | 7.304 | 61% | 58% | 59% | | |
| STRATUS SEDAN | 7.464 | 67% | 69% | 68% | 69% | 66% |
| ACCORD | 7.470 | 65% | 67% | 67% | 62% | 61% |
| MALIBU | 7.477 | 66% | 62% | 61% | 66% | 75% |
| CAMRY | 8.115 | 69% | 74% | 63% | 66% | 64% |
| SEBRING COUPE | 8.277 | 65% | 68% | 69% | 68% | 66% |
| IMPALA | 8.720 | 68% | 67% | 66% | 69% | 70% |
| MONTE CARLO | 8.731 | 68% | 66% | 65% | 66% | 68% |
| CORVETTE | 8.970 | 26% | 27% | 25% | 24% | 25% |
| TAURUS | 9.097 | 77% | 77% | 76% | 77% | 72% |
| CARAVAN | 9.928 | 92% | 98% | 99% | 103% | 85% |
| SAAB 9-3 | 10.278 | 56% | 56% | 54% | 60% | 56% |
| ENVOY | 10.539 | 54% | | 53% | 53% | 56% |
| VOLVO 60 | 10.773 | 61% | 59% | 59% | 60% | 65% |
| EXPLORER | 10.793 | 75% | 73% | 72% | 75% | 68% |
| WINDSTAR PASS | 10.959 | 83% | 84% | 81% | 82% | |
| CHRYSLER 300M | 11.471 | 57% | 58% | 55% | 56% | |
| GRAND CHEROKEE | 11.561 | 65% | 66% | 64% | 64% | 61% |
| TOWN & COUNTRY | 12.169 | 75% | 84% | 77% | 79% | 81% |
| CHEVY SUBURBAN | 12.863 | 69% | 64% | 63% | 64% | 68% |
| VIPER | 12.981 | 20% | 25% | 25% | 24% | 25% |
| AUDI A6 | 14.434 | 61% | 61% | 58% | 59% | 61% |
| MERCEDES M CLASS | 15.098 | 63% | 64% | 64% | 64% | 60% |
| BMW X5 | 15.913 | 63% | 64% | 63% | 61% | 62% |
| BMW 5 SERIES | 16.657 | 65% | 64% | 63% | 65% | 69% |
| LEXUS GS300 | 17.201 | 63% | 63% | 62% | 62% | 62% |
| ACURA RL | 18.546 | 65% | 65% | 63% | 64% | 63% |
| MERCEDES E CLASS | 20.389 | 70% | 67% | 67% | 67% | 65% |
| JAGUAR XJ6/8 | 23.897 | 62% | 62% | 61% | 64% | 59% |
| PORSCHE 911 | 27.286 | 59% | 62% | 57% | 61% | 62% |

Table A3 – Estimated markups (price – cost) and cost markups (markup/cost). Markups are in thousand dollars of 2004.

| | ACCENT | CIVIC | CAVALIER | ACCORD | CAMRY | MALIBU | TAURUS | SIENNA | CARAVAN | EXPLORER | GRAND CHEROKEE | VIPER | MERCEDES E CLASS | PORSCHE 911 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCENT | -27.49% | 0.44% | 0.29% | 0.46% | 0.62% | 0.19% | 0.16% | 0.07% | 0.07% | 0.13% | 0.06% | 0.00% | 0.01% | 0.00% |
| CIVIC | 0.06% | -19.79% | 0.35% | 0.36% | 0.27% | 0.28% | 0.25% | 0.08% | 0.14% | 0.12% | 0.07% | 0.00% | 0.01% | 0.00% |
| CAVALIER | 0.07% | 0.56% | -19.72% | 0.39% | 0.27% | 0.31% | 0.28% | 0.08% | 0.14% | 0.13% | 0.07% | 0.00% | 0.01% | 0.00% |
| ACCORD | 0.05% | 0.29% | 0.20% | -13.87% | 0.50% | 0.21% | 0.19% | 0.10% | 0.10% | 0.17% | 0.09% | 0.00% | 0.03% | 0.00% |
| CAMRY | 0.06% | 0.20% | 0.12% | 0.45% | -13.83% | 0.14% | 0.13% | 0.08% | 0.05% | 0.18% | 0.09% | 0.00% | 0.04% | 0.00% |
| MALIBU | 0.03% | 0.33% | 0.23% | 0.30% | 0.22% | -13.28% | 0.23% | 0.08% | 0.14% | 0.13% | 0.07% | 0.00% | 0.01% | 0.00% |
| TAURUS | 0.03% | 0.31% | 0.22% | 0.29% | 0.22% | 0.25% | -12.48% | 0.08% | 0.14% | 0.13% | 0.07% | 0.00% | 0.01% | 0.00% |
| SIENNA | 0.02% | 0.15% | 0.10% | 0.23% | 0.23% | 0.13% | 0.12% | -10.22% | 0.64% | 0.13% | 0.07% | 0.00% | 0.02% | 0.00% |
| CARAVAN | 0.01% | 0.18% | 0.12% | 0.15% | 0.10% | 0.15% | 0.14% | 0.42% | -9.77% | 0.10% | 0.05% | 0.00% | 0.01% | 0.00% |
| EXPLORER | 0.02% | 0.11% | 0.07% | 0.19% | 0.23% | 0.10% | 0.10% | 0.06% | 0.07% | -9.69% | 0.18% | 0.00% | 0.02% | 0.00% |
| GRAND CHEROKEE | 0.02% | 0.11% | 0.08% | 0.19% | 0.22% | 0.10% | 0.10% | 0.06% | 0.07% | 0.34% | -9.60% | 0.00% | 0.02% | 0.00% |
| VIPER | 0.00% | 0.07% | 0.08% | 0.15% | 0.08% | 0.06% | 0.06% | 0.05% | 0.03% | 0.07% | 0.05% | -6.15% | 0.07% | 0.07% |
| MERCEDES E CLASS | 0.01% | 0.05% | 0.03% | 0.18% | 0.29% | 0.06% | 0.06% | 0.05% | 0.04% | 0.10% | 0.06% | 0.00% | -5.40% | 0.01% |
| PORSCHE 911 | 0.00% | 0.02% | 0.02% | 0.09% | 0.10% | 0.03% | 0.03% | 0.05% | 0.03% | 0.06% | 0.04% | 0.01% | 0.08% | -3.80% |

Table A4 – Estimated price semi-elasticities. Each entry indicates the percent change in sales of the row model after a $1000 change in price of the column model (price changes in 2004 dollars).

| | DS | SALES | UTIL | PS | DEALERS | NMKT | COSTMK | NPLATF | STREND+ |
|---|---|---|---|---|---|---|---|---|---|
| DS | 1.000 | | | | | | | | |
| SALES | -0.133 | 1.000 | | | | | | | |
| UTIL | -0.123 | 0.293 | 1.000 | | | | | | |
| PS | 0.273 | -0.232 | -0.290 | 1.000 | | | | | |
| DEALERS | -0.115 | 0.198 | 0.188 | -0.151 | 1.000 | | | | |
| NMKT | 0.223 | -0.023 | -0.280 | 0.082 | -0.239 | 1.000 | | | |
| COSTMK | -0.034 | 0.115 | 0.024 | -0.079 | 0.274 | -0.304 | 1.000 | | |
| NPLATF | 0.152 | -0.129 | -0.033 | 0.099 | -0.140 | 0.034 | -0.106 | 1.000 | |
| STREND+ | -0.002 | 0.003 | 0.000 | -0.013 | 0.001 | -0.001 | 0.001 | 0.002 | 1.000 |
| STREND- | -0.008 | -0.005 | 0.000 | 0.010 | 0.005 | -0.003 | 0.003 | 0.002 | -0.056 |

Table A5 – Correlation matrix. Shows the correlations *within* each panel, after controlling for model FE.