# Supplier Switching Costs and Vertical Integration in the Automobile Industry

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*The Bell Journal of Economics*, Vol. 13, No. 1. (Spring, 1982), pp. 206-213.

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# Supplier switching costs and vertical integration in the automobile industry

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*This article tests a transactions cost theory of vertical integration with data from the U.S. automobile industry. Existing theory is first refined to take into account industrial know-how and the cost of transferring such know-how. A testable model is then developed, which is estimated by using probit techniques. The results support the view that transactions cost considerations surrounding the development and deepening of human skills have important ramifications for delineating efficient organizational boundaries.*

## 1. Introduction

■ In recent years, economists have begun the systematic exploration of transactions cost issues, for example, see Williamson (1975, 1979). Research has also been initiated on know-how and its relationship to the nature of the firm. Although commonly ignored in economic theory, specialized know-how has important ramifications for organizational design. In particular, vertical integration issues arise when industrial know-how, including skills, becomes deepened and specialized to a particular firm. This article attempts to draw together the literatures on transactions cost and industrial know-how, and it brings them to bear on the analysis of efficiency incentives for backward vertical integration in the U.S. automobile industry.

## 2. Vertical integration by U.S. automakers

■ In the context of the U.S. automobile industry, we are interested in explaining why firms take parts production in-house. We hypothesize that assemblers will vertically integrate when the production process, broadly defined, generates specialized, nonpatentable know-how. When production processes are of this kind, both assembler and supplier are exposed to the possibility of opportunistic recontracting. Even if the title to specialized equipment used by the supplier is held by the assembler, this need not provide protection against rent appropriation if transaction-specific know-how has been generated. The existence of transaction-specific know-how and skills and the difficulties of skill transfer mean that it will be costly to switch to an alternative supplier. (Teece, 1977, 1980). An assembler will tend to choose vertically integrated component production

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We would like to thank Charles Holloway, Paul Kleindorfer, and the referees and editors for many useful comments.

when high switching costs would otherwise lock the assembler into dependence upon a supplier and thereby expose that assembler to opportunistic recontracting or to the loss of transaction-specific know-how.

Within the vehicle manufacturing industry, supplier switching costs appear to be associated principally with development activities for new automotive parts. The design of a new vehicle model is a complex, five-year-long undertaking. Some components cannot be procured by simply announcing to suppliers performance and design requirements. The "specs" are often unknown *ex ante.* Consequently, preproduction heuristic development is critically important to the evolution of many vehicle parts. This process generates production as well as design knowledge. A suppler working in cooperation with the assembler on preproduction development gains a first-mover advantage because of knowledge acquired during development. This suggests the following testable hypothesis:

> The greater is the applications engineering effort associated with the development of any given automobile component, the higher are the expected appropriable quasi rents and, therefore, the greater is the likelihood of vertical integration of production for that component.

We shall test this hypothesis. The dependent variable we construct is dichotomous: each sample component is coded as being predominantly manufactured either in-house or by an external supplier. We next define a set of independent variables that may be expected to influence the choice between in-house production and external purchase, with our primary interest centering upon the influence of applications engineering. We then employ probit analysis to estimate the relationship between the independent variables and our measure of vertical integration.

To form the dependent variable, a list of 133 automotive components was obtained from an assembler. For each of the components, we ascertained the extent of vertical integration by General Motors and Ford for U.S. production in 1976. Each of the 133 components was recorded as either produced internally or sourced externally. For proprietary reasons, data about the exact percentage of each item in our sample that was manufactured in-house were not divulged. Hence, we took internal production of 80 percent or more of a component as an operational definition of integrated production. Taken together, the 133 component groupings include most of the major items that go into a complete vehicle.[1] Thus, the sample provides a representative picture of vertically integrated production for Ford and General Motors in 1976. The data are presented in Table 1.

Consider the independent variables. An excellent operational measure of applications engineering effort is the cost of developing a given component. Firms in the industry have these data on a component-by-component basis, but because of the data's proprietary nature, we were not able to gain direct access to them. However, a source within the industry who is privy to the data provided an engineering cost rating for our sample of automotive components.[2] This yielded a surrogate measure of relative engineering

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[1] One conspicuous absence, however, is that of tires, none of which are produced by either Ford or General Motors. It should also be noted that two items, steel and vinyl, which are included in the sample, might better be classed as "basic materials" rather than components, as both are further upstream in the production process than most of the other items in the sample. However, the list submitted by our sources was accepted without alteration except for the elimination of "miscellaneous" categories and unidentifiable part names.

[2] The source was the design engineer for one of the major U.S. automakers who had responsibility for supervising development of a new generation of small, fuel-efficient vehicles to be manufactured in the United States. The reliability of his ratings was tested by obtaining a separate set of ratings from another automotive engineer. The two sets of ratings shared a correlation coefficient of .8, adding confidence that our ratings were a meaningful surrogate for the underlying construct.

**TABLE 1 The Backward Vertical Integration of Ford and General Motors**
("1" denotes 80 percent or more of component requirements produced in-house as of 1976.)

| Part Category | Ford | GM |
|---|---|---|
| • BODY | | |
| Body Sheet Metal | 1 | 1 |
| Exterior Ornamentation | | |
| Paint (Topcoat) | | |
| Primer | | |
| Bumpers | 1 | 1 |
| Body Lamps | 1 | 1 |
| Sealed Beam Bulbs | | 1 |
| Weatherstrip | | |
| Mirrors—Outside | | |
| Mirrors—Inside | | 1 |
| Interior Trim | 1 | 1 |
| Interior Ornamentation | | 1 |
| Carpeting & Mats | | |
| Headlining | 1 | 1 |
| Safety Belts | | |
| Inertia Locks | | |
| Lock—Cylinders | | |
| Door Handles | | 1 |
| Hinges (Door, Hood, Decklid) | 1 | 1 |
| Window Regulator (Power) | | 1 |
| Window Regulator (Manual) | 1 | 1 |
| Glass | 1 | |
| Windshield Wiper Motor | 1 | 1 |
| Windshield Washer System | 1 | 1 |
| Crash Pad | | 1 |
| Seat Frame & Springs | | |
| Seat Pad | | 1 |
| Seat Tracks (Man. & Elec.) | | 1 |
| Lamp Bulbs | | 1 |
| Head Restraints | 1 | 1 |
| Headlamp Assembly | 1 | 1 |
| Sealers & Insulation | | |
| Armrests | | 1 |
| Grill | | |
| Frame | | |
| Jack & Wrench | | |
| Engine Mounts | | |
| • ENGINE | | |
| Engine Stampings | 1 | 1 |
| Cylinder Head | 1 | 1 |
| Block | 1 | 1 |
| Manifold (Intake & Exhaust) | 1 | 1 |
| Crankshaft | 1 | 1 |
| Camshaft | 1 | 1 |
| Piston | 1 | N/A |
| Piston Ring | | |
| Valves (Intake & Exhaust) | 1 | N/A |
| Radiator | 1 | 1 |
| Fan | | |
| Air Cleaner | 1 | 1 |
| Air Cleaner Element | | 1 |
| Carburetor | | 1 |
| Fuel Pump | | 1 |
| Starter | 1 | 1 |
| Distributor | 1 | 1 |
| Spark Plug | | 1 |
| Ignition Coil | 1 | 1 |
| Oil Filter | 1 | 1 |
| • EMISSION COMPONENTS | | |
| Catalytic Converter | | 1 |
| Air Pump | | 1 |
| Carbon Cannister | 1 | 1 |
| Substrate & Coating | | |
| PCV, EGR, etc. Valves | | |
| • CHASSIS | | |
| W.C., H.C. (Optional) | | |
| Wheel Covers & Hub Caps (Std.) | | 1 |
| Coil Springs | 1 | 1 |
| Leaf Springs | | 1 |
| Shock Absorbers | 1 | 1 |
| Upper & Lower Arms | 1 | 1 |
| Spindle Assembly | 1 | 1 |
| Driveshaft Assembly | 1 | 1 |
| Wheels | 1 | |
| Wires | | |
| Rear Axle | 1 | 1 |
| Drums | | |
| Master Brake Cylinder | | |
| Power Brake Booster | | 1 |
| Parking Brake | | |
| Muffler | | |
| Tailpipe/Inletpipe | | |
| Brakes | | |
| Disc Caliper & Rotor | | 1 |
| Front Suspension | 1 | 1 |
| Rear Suspension | 1 | 1 |
| • TRANSMISSION | | |
| Auto. Transmission Assy. | 1 | 1 |
| Auto. Transmission Cases | 1 | 1 |
| Manual Trans. Assembly | | 1 |
| • STEERING | | |
| Manual Steering Gear | 1 | 1 |
| Power Steering Gear | 1 | 1 |
| Steering Linkage | | 1 |
| Steering Column | 1 | 1 |
| Steering Wheel | | 1 |
| Power Steering Pump | | 1 |
| Steering Assembly | 1 | 1 |
| • FUEL | | |
| Fuel Tank | 1 | 1 |
| Gas Cap | | |
| • VENTILATION | | |
| A/C Assembly | 1 | 1 |
| Evaporator | 1 | 1 |
| Expansion Valve | | 1 |
| Vacuum Motors | | 1 |
| Blower Wheels | | |
| Blower Motors | 1 | 1 |
| Heater Assembly | 1 | 1 |
| Heater Core | 1 | 1 |
| Compressor | | 1 |
| Clutch | | 1 |
| ATC Components | | 1 |
| Condensor | 1 | 1 |
| Dehydrator/Receiver | | N/A |
| Hose Assemblies | | N/A |

**TABLE 1** (*Continued*)

| Part Category | Ford | GM | Part Category | Ford | GM |
|---|---|---|---|---|---|
| • ELECTRICAL | | | Antenna | | 1 |
| Instrument Cluster & Panel | 1 | 1 | Speed Control System | 1 | 1 |
| Speedometer Cable Assembly | | 1 | Clock | | |
| Fuel Sender | 1 | 1 | Switches | | |
| Alternator | 1 | 1 | • OTHER | | |
| Regulator | 1 | 1 | Tubing (Brake/Fuel Lines) | | |
| Battery | | 1 | Antifreeze | | |
| Horn | 1 | 1 | Oils & Grease | | |
| Battery Cables | | 1 | Steel | | |
| Wiring Harness | | 1 | Standard Parts, Fasteners | | |
| Radio | 1 | 1 | Vinyl | 1 | |
| Tape Player | | 1 | Water Pump Assembly | 1 | 1 |
| Speakers | | 1 | Oil Pump | 1 | |

effort. The rating was done on a 10-point scale with each component considered to require from "none" to "a lot" of engineering investment. We assume that such a rating scale provides a reasonable enough approximation to interval scaled data to allow use of parametric procedures.

To avoid misspecifications of the model, three sets of control variables are introduced. The first control variable distinguishes components that are specific to a company from those that are generic. Some of the components included in the sample (e.g., fasteners) are not designed specifically for any single automaker. These are items for which traditional spot market contracting may be expected to operate quite well; and for these components there would appear to be no incentive to integrate. However, components that are not specific to a single assembler's product may be expected to be among those rated as requiring the least applications engineering. To ensure that the engineering variable does not indicate a statistical relationship with integration that actually arises because nonspecific components will not be attractive integration candidates, a "component specificity" variable is introduced into the model.

The determination as to which sample components represent assembler-specific parts and which do not was accomplished with the cooperation of a replacement parts wholesaler. Company officials were asked to isolate those components for which identification of the manufacturer, make, and model of the automobile was not necessary to procure a replacement unit.[3] We assume that those components for which make and model information is not critical are not company-specific in original assembly. Using this procedure, a group of 30 items was identified as non-company-specific.

The second control variable relates to the identity of the sample firms. Because we developed a combined cross sectional model aggregating both Ford and General Motor's data, we include a dummy variable to control for systematic differences between these two firms with regard to vertical integration.

The third set of control variables relate to systems effects. The automobile represents not simply an assemblage of parts, but a "system"—a set of objects with relationships between the objects and their attributes (Hall, 1973, p. 103). In the vehicle "system," the "objects" are the individual components, and the relationships between components

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[3] The actual question was: "Please examine the following list of 133 automotive components and indicate which of the noncaptive items on the list could be procured as replacement units without necessarily having to know the manufacturer, make, and model of the vehicle for which the replacement is sought. That is, which of the following categories of parts may be expected to be largely common across several manufacturers' vehicles."

consist principally of their mechanical or electrical interrelations and their "packaging"—the latter being the industry's term for physically fitting all components within the dimensions of the body. Clearly, design and implementation for any system as complex as an automobile must be tightly coordinated.[4] Because of the superior coordinating properties of vertical integration,[5] the degree to which any given component's design affects the performance or packaging of other components is a potentially important consideration in explaining the likelihood of vertically integrated production of the given component (Armour and Teece, 1980).

As shown in Table 1, the components were first grouped into nine categories (body, engine, emission components, chassis, transmission, steering, fuel, ventilation, electrical) and a tenth miscellaneous category. These categories were subsequently collapsed into six subsystems by merging emissions with engine, transmission and steering with chassis, and fuel tank and cap with body. The aggregation was based on expert evaluation of the degree of technical interrelatedness among the components. Vertical integration is predicted for components with large systems effects. Since we are unable to rank the subsystems according to the degree of interrelatedness, we simply posit that different subsystems will display different levels of vertical integration. Thus, a set of dummy variables was introduced into the model to represent each component's membership in a subsystem.

The predictor variables were combined into a single model estimated by probit techniques. A vector of parameter estimates for $\beta$ was derived to maximize the log likelihood function:

$$L = \sum_{i=1}^{n} y_i \ln F(x_i'\beta) + \sum_{i=1}^{n} (1 - y_i) \ln [1 - F(x_i'\beta)],$$

where $y_i$ is 1 if the $i$th component is integrated in production and zero otherwise; $x_i$ is the vector of values of the independent variables for the $i$th observation; and $F(x_i'\beta)$ takes the specific form:

$$F(x_i'\beta) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x_i'\beta} e^{-u^2/2} du.$$

The $x_i$ vector contains, for each sample point $i$, the values of the eight independent variables defined below:

$$ENGINEERING_i = \left\{ \begin{array}{l} \text{rating of the } i\text{th observation on the amount of engineering} \\ \quad \text{effort required in designing the part;} \end{array} \right.$$

$$SPECIFIC_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to a part specific to a single} \\ & \quad \text{assembler;} \\ 0 & \text{otherwise;} \end{cases}$$

$$COMPANY_i = \begin{cases} 1 & \text{if the } i\text{th observation was from General Motors;} \\ 0 & \text{if the } i\text{th observation was from Ford;} \end{cases}$$

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[4] White observes that: "The complex process of designing, producing, testing, and modifying an automobile requires a high degree of coordination. Engine, transmission, frame, body, brakes, windshield, and other components all have to perform well with each other and have to be in the right place at the right time in the right quantities" (White, 1971, p. 78).

[5] Vertical integration permits executive fiat to be used to achieve the requisite coordination in a timely fashion (Williamson, 1975). Scherer also notes the coordination benefits of integration and offers an example from the auto industry: "The benefits from integration also increase with the complexity of product component interrelationships. It is easier to make the various parts of an automobile fit together when all parties to the coordination effort work for the same boss than when design changes must be processed through a purchasing office" (Scherer, 1980, p. 90).

$$ENGINE_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to an engine and emissions subsystem part;} \\ 0 & \text{otherwise;} \end{cases}$$

$$CHASSIS_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to a chassis, transmission, and steering subsystem part;} \\ 0 & \text{otherwise;} \end{cases}$$

$$VENTILATION_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to a ventilation subsystem part;} \\ 0 & \text{otherwise.} \end{cases}$$

$$ELECTRICAL_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to an electrical subsystem part;} \\ 0 & \text{otherwise;} \end{cases}$$

$$BODY_i = \begin{cases} 1 & \text{if the } i\text{th observation corresponds to a body, fuel tank and cap subsystem part;} \\ 0 & \text{otherwise.} \end{cases}$$

The parameter estimates for $\beta_1$ through $\beta_8$, the asymptotic $t$-statistics corresponding to these eight predictor variables, and the model summary statistic are given in Table 2.

Recall that in-house production of 80% or more of a component's output was selected as the operational definition of vertical integration. To establish the robustness of the

**TABLE 2 Probit Coefficients, Asymptotic $t$-Statistics (in parentheses), and $\chi^2$-Statistic in Equation to Explain Vertical Integration**

(Defined upon three thresholds for percentage of in-house parts production.)

| Coefficient Estimated | Related Variable | Vertical Integration Defined as In-house Production of: ≥70% | ≥80% | ≥90% |
|---|---|---|---|---|
| $\beta_1$ | *ENGINEERING* | 0.1319<br>(3.24)* | 0.1461<br>(3.57)* | 0.1453<br>(3.54)* |
| $\beta_2$ | *SPECIFIC* | 0.8773<br>(3.64)* | 0.8186<br>(3.33)* | 0.7902<br>(3.15)* |
| $\beta_3$ | *COMPANY* | 0.7388<br>(4.22)* | 0.7125<br>(4.05)* | 0.9010<br>(5.08)* |
| $\beta_4$ | *ENGINE* | 0.5521<br>(1.21) | 0.5348<br>(1.17) | 0.7168<br>(1.47) |
| $\beta_5$ | *CHASSIS* | 0.0615<br>(0.138) | 0.0003<br>(0.001) | 0.03051<br>(0.637) |
| $\beta_6$ | *VENTILATION* | 0.3620<br>(0.733) | 0.4903<br>(0.983) | 0.6552<br>(1.25) |
| $\beta_7$ | *ELECTRICAL* | 0.6861<br>(1.48) | 0.6905<br>(1.49) | 1.085<br>(2.18)† |
| $\beta_8$ | *BODY* | 0.0857<br>(0.201) | −0.2293<br>(−0.532) | 0.1152<br>(0.248) |
| $\chi^2$ Value | | 110.064* | 111.291* | 126.676* |

* Indicates significance beyond the .001 level.

† Indicates significance beyond the .05 level.

results, we also obtained a listing of those items which would be considered integrated were the cutoff changed to 70% and then to 90%.

The principal point to note about the results in Table 2 is that regardless of the threshold chosen, the variable used as a proxy for transaction-specific skills ("engineering") is highly significant. The development effort associated with the design of any given automotive component is shown to be positively related to the likelihood of vertically integrated production of that component, thereby confirming the central hypothesis of this article.

Second, the coefficient on the "*SPECIFIC*" variable is also positive and statistically significant, which lends support to the hypothesis that only components specific to a single assembler will be candidates for vertical integration. It can also be seen that the coefficient for the "*COMPANY*" variable is positive and statistically significant, thereby indicating that General Motors is more integrated into component production than is Ford.

Finally, the systems-effects hypothesis is only mildly supported by the probit analysis. With the exception of the "*ELECTRICAL*" variable in the $\geq 90\%$ integration threshold case, none of the coefficients on the five dummy variables taken alone indicates a significant relationship with backward integration. Nevertheless, the set of five systems effect dummies, taken together, significantly contributed to the explanatory power of the model.

In general, the change in magnitude of the coefficients was minor as the definition of vertical integration was altered. The variation was the greatest among the individual subsystem variables that, with the one exception of the electrical subsystem variable, were not found to be significantly different from zero.

## 3. Conclusion

■ Transactions cost considerations surrounding the development and deepening of human skills appear to have important ramifications for vertical integration in the automobile industry, thereby supporting the transactions cost paradigm advanced by Williamson. GM and Ford are more likely to bring component design and manufacturing in-house if relying on suppliers for preproduction development service will provide suppliers with an exploitable first-mover advantage. We posit that this is a result of the high switching costs entailed if the supplier acquires transaction specific know-how at the assembler's expense. Since know-how cannot simply be transferred from supplier to supplier like a book of blueprints (Winter, 1980), backward integration is the more prudent course of action. General Motors and Ford also have a preference for backward vertical integration when the components are firm-specific and their design must be highly coordinated with other parts of the automobile system.

Hence, the vertical structure of GM and Ford appears to be based at least in part on efficiency considerations. Specifically, the structure appears to be designed to take advantage of the coordinating properties of hierarchies as well as the ability of internal organization to reduce the exposure of the automakers to opportunism from suppliers—a hazard which is apparently absent in the less integrated Japanese industry[6] where "the relationship between the major auto firm and its satellite suppliers is one of total cooperation" (Ouchi, 1981, p. 19).

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[6] We posit that cooperation between the auto companies and remaining suppliers will also characterize the U.S. industry because the integrated and "quasi-integrated" (Monteverde and Teece, 1982) structure of the industry has eliminated most occasions for opportunistic rent appropriation.

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*The Bell Journal of Economics*, Vol. 13, No. 1. (Spring, 1982), pp. 206-213.
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## [Footnotes]

[6] **Appropriable Rents and Quasi-Vertical Integration**
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