Vertical Integration and the Industry Lifecycle: Evidence from the Early U.S. Auto Industry

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Abstract

At least since George’s Stigler’s (1951) classic paper, it has been thought that firms’
vertical integration choices are sensitive to the stage of industry evolution in which they
find themselves. Perhaps in large part because of lack of data, however, patterns of
vertical integration or disintegration behavior over the lifecycle have been little studied in
large samples. In this paper, we empirical investigate three types of possible impacts on
firm’s vertical integration choices, each of which stems from the industry lifecycle. First,
we hypothesize that the emergence of a dominant design in an industry, as emphasized in
some industry lifecycle theories, is associated with vertical disintegration because of the
standardization of components that dominant designs tend to promote. Second, we posit
that firms selling at higher price points, because they are attempting to differentiate their
products by incorporating unique components, will tend to be more vertically integrated
than their lower-price rivals. Finally, we hypothesize that firms with more early
production experience, because they tend to develop superior production capability
relative to suppliers, will tend to be more vertically integrated into components. We find
evidence for all three effects in data from the early U.S. auto industry. Our data cover the
1920-1931: the years leading up to, and including, those in which the major shakeout in
the industry occurred. We draw implications for organizational modularity, and for
endogenizing transaction costs.
Since the publication of Utterback and Abernathy’s (1975, 1978) seminal work on the product life cycle, strategy scholars have sought to understand its implications for firm strategy across that cycle (e.g., Porter 1980; Baum and McGahan 2004). Utterback and Abernathy originally postulated that products develop in distinct phases; an early period of fragmentation in product design is followed by rapid entry brought on by the emergence of a single dominant design, which is in turn followed by a shakeout, and finally maturity. A central question about the industry lifecycle that has been little studied empirically, however, is whether and how a firm’s vertical boundaries may be affected by the stage of lifecycle in which the firm finds itself (e.g., Langlois and Robertson 1995; Klepper 1997). Are there patterns of vertical integration or disintegration across the stages of the industry lifecycle? Do these patterns reflect firms’ choices of competitive strategy, and if so, how? In this paper, we empirically examine several possible impacts of the industry lifecycle on firms’ vertical integration choices.

Transaction cost economics (TCE), the dominant theory of vertical integration in the contemporary strategy literature, does not address possible impacts of the industry lifecycle on firm boundaries (e.g., Williamson 1975, 1985; Klein, Crawford and Alchian 1978). In part this is because TCE postulates that transaction-level asset specificity is the main determinant of the vertical integration decision, but takes the asset specificity involved in a particular transaction as exogenous. An important way in which the industry lifecycle might affect firm boundaries, however, is through industry-wide changes in the asset specificity levels of product components as the lifecycle proceeds. For example, as a dominant design emerges in an industry, product components may

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become increasingly standardized, leading to a pattern of decreasing vertical integration as the dominant design emerges.

A second way in which the industry lifecycle might influence firm’s vertical boundary choices is through its affects on firms’ competitive positioning strategies. As Klepper and colleagues have argued, and shown empirically, industry evolution is driven in large measure by firm’s choices about the directions in which to innovate, especially product vs. process innovation (e.g., Klepper and Graddy 1990; Klepper 1996; Klepper 2002). These choices about directions of innovation are also informed by individual firms’ choices about how to position their products on the market. Several scholars have argued, however, that competitive positioning choices can systematically impact the asset specificity levels of various inputs to the production process, which in turn impact vertical integration decisions (Nickerson 1997; Ghosh and John 1999; Nickerson, Hamilton and Wada 2001). Thus, whereas Williamson (1993) doubted the impact of competitive positioning on governance choices, this effect may in fact be important, particularly in a period of industry evolution in which technological opportunities are abundant, innovation is rapid, and the scope for differential positioning is significant (Lawless and Anderson 1996).

A third route through which the industry lifecycle stage might affect firms’ vertical integration choices is through the effects of the lifecycle stage on the production capabilities of component buyers compared to potential component suppliers. Klepper and colleagues, for example, have found evidence that first movers in an industry tend to build up production capabilities early in their histories that aid them greatly as competition later becomes increasingly based on production costs and process innovation.
rather than overall product design innovation (Klepper and Graddy 1990; Klepper 2002). Other scholars have argued and found that a firm’s superior production capabilities vis-à-vis suppliers can be an important reason for vertical integration (Demsetz 1988; Kogut and Zander 1992; Langlois and Robertson 1995; Argyres 1996; Leiblein and Miller 2003; Jacobides and Winter 2005; Jacobides and Hitt 2005). Therefore, if relative production capabilities as between buyers and suppliers tend to differ across stages of the industry lifecycle stage, then lifecycle effects on vertical integration may operate through their impact on relative production capabilities.

Our empirical analysis attempts to measure these three possible impacts of the industry lifecycle on firm’s vertical boundaries: dominant design effects, competitive positioning effects, and production capabilities effects. We assess the importance of these three effects by analyzing a dataset from the early U.S. auto industry during the period 1917-1931. It was during this period that the dominant design was becoming established in the industry (Abernathy 1978), when innovation was rapid as firms experimented with different kinds of component technologies, and when the major, dramatic shakeout in the industry occurred (see Figure 1). Thus, studying this period offers an opportunity for understanding how the boundaries firms evolve during the key transitional stage of industrial development, and for understanding the role of firms’ competitive positioning choices in that evolution.

The remainder of the paper proceeds as follows. The next section develops our hypotheses, based on industry lifecycle theories and transaction cost theory. The following section describes our data. We then explain our estimation approach, and discuss our results. A conclusion ends the paper.
HYPOTHESIS DEVELOPMENT

Theories of the Industry Lifecycle

According to the theory of the “product lifecycle” originally presented by Utterback and Abernathy, in the early stage of an industry’s evolution firms compete based on alternate “product designs” or overall “product conceptions”. These designs differ from each other in fundamental ways -- for example, they may be based on different physical principles or engineering solutions. The early stage of industry development is thus in a period of experimentation by many firms. Eventually, a dominant design emerges that represents an effective technical solution to the engineering problems posed by the product. A product design is defined as “the concepts that define how the components of the product interact or relate to each other” (Christensen, Suarez and Utterback 1998, p. S208), so that a dominant design consists of standardized components interacting through standardized engineering interfaces (Afuah and Utterback 1997).

Once a dominant design becomes established, new firms enter at a faster rate, and product imitation is widespread. The existence of a dominant design also leads to a decline in the rate of overall product design innovation, while the rate of process innovation increases. Firms increasingly compete on the basis of economies of scale and production knowhow rather than on alternative product designs per se. Firms producing products that do not conform to the dominant design, and firms that are relatively inefficient in terms of mass production, exit relatively rapidly. Eventually, the industry stabilizes around a few large firms competing mostly on process innovation and cost.
Several empirical studies have produced findings that are broadly consistent with this theory (e.g., Suarez and Utterback 1995; Christensen et al. 1998; Tegarden et al. 1999).

Klepper (1996)’s model of the industry lifecycle represents an effort to put lifecycle theory on a rigorous basis in economics. In Klepper’s model, the early stage of an industry’s evolution features entry by firms that differ in their product innovation expertise and process R&D capability. In this stage, smaller firms develop different variants of the product that are aimed at particular customer segments, for which they receive a price premium. Larger firms compete on process R&D and cost. Firms observe each others’ product innovations, and over time incorporate each others’ innovations into an industry-standard product. Buyers of the different variants begin to buy the standard product, the demand for the standard product rises rapidly, and this stimulates new entry. Eventually, a shakeout occurs in which firms with lower output levels exit. Smaller firms are disadvantaged because the value of a unit of cost-reducing process R&D is assumed to be greater for firms with higher output levels, and because the adjustment costs that firms incur to increase their output levels are assumed to be convex. Thus, firms that entered earlier build up greater process innovation capability than rivals that entered later, are more likely to survive the shakeout stage. In the maturity stage of the lifecycle, price declines, and competition continues to occur on the basis of process R&D capability aimed at lowering cost. Klepper and colleagues have conducted several empirical studies covering multiple industries, and have found patterns consistent with this basic model (e.g., Gort and Klepper 1982; Klepper and Graddy 1990; Klepper 2002).

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1 The underlying mechanism driving the emergence of product standardization is thus different in the Utterback/Abernathy and Klepper lifecycle theories. For Klepper (1996) product standardization emerges endogenously from firms’ choices about how to innovate, whereas for Utterback/Abernathy it appears to be an exogenously determined engineering imperative. Our own analysis does not depend on this difference between the mechanisms, and does attempt to distinguish them empirically.
Dominant Design Effect on Vertical Integration

A key inspiration for both the Utterback/Abernathy and Klepper theories came from Abernathy’s (1978) historical study of the U.S. automobile industry. Abernathy explained that as the early auto industry developed, automobiles became increasingly homogeneous in their overall design, i.e., in the ways in which their components interact. In the early U.S. auto industry, for example, steam engines and electric vehicles gradually gave way to internal combustion, water-cooled gasoline engines. Power train configurations with the engine placed at the front became standard during the early part of the 20th century. Steering wheels replaced other kinds of steering controls, and by 1918 all mass produced cars had the steering wheel on the left side. Shaft transmissions became increasingly common. Electric ignitions replaced mechanical and magnetic starters. Whereas many car models were open during the early period of the industry, by 1926 over 70% of all cars sold in the U.S. featured all steel closed bodies (Abernathy 1978). At this point, according to Abernathy and Utterback (1978), a dominant design for the automobile had become fully established, and product design innovation slowed significantly, while process innovation sped up. As Figure 1 indicates, the emergence of a dominant design for automobiles in the U.S. corresponds to the beginning of the major shakeout in the industry.

While transaction cost theory has not addressed the industry lifecycle, it does postulate that as components of a product become standardized, producers of the product

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2 Klepper (1997), however, presents some evidence that process innovation in automobiles and other industries was significant even before the emergence of any dominant design in those industries. This evidence calls into question the basic Utterback/Abernathy account of the industry lifecycle. Our own analysis only requires that automobiles became more homogenous in their overall design during the period of our study. It does not depend on the relative importance of process innovation in the earlier vs. later stages of the lifecycle.
will increasingly buy those components on the market rather than make them internally. The reason is that hierarchies are more efficient than markets for organizing production only when asset specificity is high and therefore contracting hazards are present. Hierarchies can deal better with such hazards than markets because of the availability of forbearance and fiat as a last resort (Williamson 1985, 1991). When products are standardized, however, so that asset specificity is low and buyers can switch to alternate suppliers easily and at low cost, market governance is more efficient because it offers higher powered incentives to external suppliers than hierarchies can offer to internal supply divisions (Williamson 1985). In addition, external suppliers may be better able to capture economies of scale in production, because vertically integrated producers usually cannot sell excess component output to rivals (Williamson 1975). Finally, vertically integrated firms are thought to suffer from bureaucratic costs that suppliers may avoid (Williamson 1985). There is a large empirical literature on make-or-buy decisions that finds substantial evidence consistent with this theory of vertical boundaries (for surveys, see Shelanski and Klein 1995; Klein 2005).

Combining lifecycle theories and transaction cost theory therefore suggests that as a dominant design emerges, incumbent firms will tend to vertically disintegrate component procurement, as those components become standardized and asset specificity levels fall, or will exit due to excessive bureaucratic costs and weak incentive intensity. In addition, successful new entrants will tend to be less vertically integrated than firms that entered earlier. Therefore, with time firms on average should become less vertically integrated. Therefore, we hypothesize that:
H1: Firms reduce the range of components into which they are vertically integrated during the period of industry evolution in which a dominant design or standardized product is becoming established.

Note that this hypothesis postulates a different mechanism driving vertical disintegration than that theorized by Stigler (1951). Stigler argued that young industries tend to be the vertically integrated until industry output levels rise enough to allow independent suppliers to reach minimum efficient. Whereas Stigler emphasized economies of scale considerations, industry lifecycle and transaction cost effects are the basis of our hypothesis here. Note also that the hypothesis is also consistent with recent literature that argues that as products become more modular, organizational forms tend to become more modular as well (e.g., Sanchez and Mahoney 1996; Schilling and Steensma 2001).

Competitive Positioning Effect on Vertical Integration

According to industry lifecycle theory, once a dominant design has become established, firms focus their efforts either on cost reduction, or on innovation and differentiation of product components, but not on innovation in the overall product design that combines the components (Afuah and Utterback 1997, Christensen, Suarez and Utterback 1998). Lawless and Anderson (1996) argue that a major advance in the technological regime within an industry promotes the emergence of new market niches. During the period covered by our study, a number of larger auto firms competed mostly

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3 In a prior paper (Anonymous 2006), we argued that production of certain key components of a product may become internalized more readily during a shakeout, as firms seek to exploit process capabilities to achieve cost reduction for these high cost components. We found evidence supporting this hypothesis in the data on engine procurement. The current paper’s argument concerns vertical integration across a range of components, however, rather than vertical integration of a key component. Thus, we predict that during a shakeout, fewer components in total will be vertically integrated, even if a few key components are increasingly vertically integrated.
by aiming to capture economies of scale in production, and then to sell cars in in the middle and lower prices ranges in the market. These competitors included Ford, most of the General Motors nameplates of the time (Buick, Oakland, Chevrolet, Oldsmobile, but not Cadillac), Nash, and Hudson. There were also many examples of smaller firms attempting to differentiate their cars from more basic cars by developing certain features of their automobiles, even as they maintained adherence to the dominant design. Thus, whereas very early in the 20th century smaller firms often attempted to differentiate themselves based on radically different combinations of components, during the period of our study, differentiation increasingly occurred within the given dominant design, at the level of a few individual components or particular product characteristics.

Some firms, notably the famous “3 P’s” (Packard, Peerless, Pierce-Arrow) tried to differentiate by building bigger, more comfortable cars with luxurious interiors. Differentiation in body design elements was also very active during the 1920’s, with firms offering distinctive radiator designs, headlight placements, running board and fender shapes, wheel designs and the like (e.g., Apperson, Biddle, Crawford, Fiat, duPont, Jordan, Velie). Some firms aimed to differentiate by using bigger, more powerful engines to generate more speed for either roadsters (e.g., duPont, Jordan) or luxury cars (e.g., Cunningham, McFarlan, Peerless). Later in the 1920’s, some firms began to compete on safety elements, with more expensive cars featuring, for example, front wheel brakes that used conventional or new hydraulic technology (e.g., Stutz, Kissel, Packard). Still other firms offered more effective cooling systems (e.g., Fox, Franklin), better ignition systems for easier starting (McFarlan, White, Winton, Franklin) suspension systems for a smoother ride (e.g., Marmon, Roamer), or transmission systems
for easier gear shifting (e.g., Owen, Premier, Stutz). The smaller firms in this period thus aimed to focus their differentiation on one or a few components, even as the remaining components in their overall designs became increasingly standardized. Larger differentiators, such as GM’s Cadillac and Ford’s Lincoln, attempted to differentiate on several major components simultaneously (e.g., engine, interior, etc.)

Often, achieving superior component performance involved developing proprietary technologies for those components. For example, Stutz achieved its superior transmission system by developing an unusual 3-speed gearbox that was joined with the rear axle. Fox and Franklin innovated with proprietary air-cooled engines that used the first fan blowers. Roamer’s rear suspension relied on a unique system of double cantilever springs. White developed a magneto ignition, while Winton offered an unusual compressed-air starter. Cunningham developed one of the first V-8 engines. Marmon offered a unique double-three point suspension, with a separate subframe for engine and transmission. Kissel touted its internally expanding hydraulic brakes. Moon innovated with an efficient 6 cylinder engine that featured four main bearings, a rarity at the time. Other companies emphasized uniquely shaped body components for distinctive styling. Biddle developed a unique, pointed radiator, while Fiat’s radiators were distinctively pear-shaped. Crawford’s body design featured military-type fenders. DuPont’s radiator grille was one of the first of its kind. Velie’s raked “A” pillar gave its windshield a larger-than-typical angle from the top to the base.

While in some cases these differentiating components were purchased from external suppliers (e.g., high-performance engines), our proposition, consistent with transaction cost reasoning, is that by and large, unique components would tended to have

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been produced internally. As transaction theory emphasizes, transactions for components
that are unique to a buyer, or even a particular car model, can be hazardous. In such
transactions, the supplier will usually be required to devote engineering effort, factory
space, or machinery to the development and production of such component – investments
that are buyer-specific and therefore vulnerable to hold-up by an opportunistic buyer
(Williamson 1985). In addition, the buyer may be at risk if the supplier opportunistically
passes on proprietary information about the component’s characteristics or manufacture
to the buyer’s rivals, or uses that information to compete against the buyer (Teece 1986,
Williamson 1991). Finally, to the extent that a buyer’s reputation for quality depends on
the performance of its unique components, and to the extent that a supplier’s reputation is
less vulnerable to quality shading, then the buyer is again at risk by relying on that
external supplier (Klein and Leffler 1981; Barzel 1982). Indeed, one company,
Locomobile, prided itself on its lack of reliance on external suppliers of components,
advertising that “no stock parts or ready-made units are permitted” (Georgano 1982, pp.
383). According the transaction cost theory, then, internal production of unique
components is more efficient than market procurement.

Our dataset unfortunately does not include complete information on the model
years in which differentiating firms used particular differentiated components. However,
we are able to make a number of correspondences between make-buy behavior and the
firms and their differentiated component types mentioned above. For example, Crawford
differentiated on body design, and internally produced those bodies. Cunningham
differentiated on engines, and made them all internally. In early 1920’s when Stutz was
differentiating on the gearbox/rear axle combination, it internally produced its
transmissions and rear axles. Marmon’s unique subframes were also made rather than bought. Premier offered differentiated transmission systems, and made those systems itself. Velie’s unique windshield design was based on a body that was made, not bought. Now, there were some exceptions to this pattern. McFarlan, Winton, and Franklin, for example, chose to buy, rather than make, ignition systems, even though they were attempting differentiate their cars based on the innovation in those systems. Similarly, Moon differentiated on 6-cylinder engines, yet purchased them on the market. Our argument suggests that these latter firms were exceptions, and were probably misaligned with respect to these key transactions.

We argue, then, that differentiated auto producers, because they competed based on unique components more than did cost-based competitors, were likely to be more vertically integrated into components. This argument is in the spirit of Nickerson (1997) and Ghosh and John (1999), who pointed out that a firm’s positioning choices often determine the level of asset specificity associated with the assets in which the firm invests. Williamson (1993) had earlier rejected the notion that competitive positioning could be an important determinant of firm performance over the longer term, arguing that such positions are easily imitated. Nickerson, Hamilton and Wada (2001), however, found that overnight delivery carriers aiming for faster delivery times than their competitors also used more idiosyncratic information technology (IT), and vertically integrated the transactions in which such technology was used. Carriers offering somewhat slower delivery times but lower prices, on the other hand, used more generic IT, and less vertical integration. Thus, firms’ positioning choices, asset profiles, and governance choices were interdependent in that case.
Given that competition was quite strong during the period of our study (in view of the very high exit rates during our sample period), and given that the 11 year period is presumably long enough for selection and adaptation to have occurred (Williamson 1985), we assume that inefficient firms eventually righted themselves or were forced to exit. Therefore, because higher priced autos tended to feature more differentiated components, while lower-priced cars were more likely to use mostly standardized components, we hypothesize that:

**H2:** Firms selling higher-priced products tend to be vertically integrated into a broader range of components than rivals selling lower-priced products.

**Production Capabilities Effect on Vertical Integration**

A number of scholars have argued that the quality of a firm’s production capabilities for inputs relative to (potential) suppliers’ capabilities may be important drivers of vertical integration decisions (Demsetz 1988; Kogut and Zander 1992). Because firms may not be able to build or acquire capabilities quickly and at low cost, in the short run at least, differential capabilities may be the primary consideration in a decision to make or buy (e.g., Langlois 1992; Argyres 1996). Large sample empirical studies have found that differential production costs beyond those caused by differential economies of scale between buyers and suppliers can be important causes of vertical integration or disintegration (Leiblein and Miller 2003; Jacobides 2004).5

A major thrust of Klepper and colleagues’ theoretical and empirical studies of the industry lifecycle, however, is that early movers tend to develop superior production capabilities vis-à-vis rivals. The essential notion is that early movers have more time to

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5 While these studies tend to present production cost-based explanations of vertical integration decisions as competing with transaction cost-based explanations, Argyres and Zenger (2006) argue that the two kinds of explanation are usually logically inseparable.
develop production experience than late movers. Later entrants, even if they enter as relatively large firms (with high initial sales) cannot match the eventual efficiency of the early entrants because investments in process innovation capacity have greater marginal value the larger is the firm (Cohen and Klepper 1996; Klepper 1996). By the time later entrants enter, early entrants have already made greater cumulative investments in process innovation capacity. This eventually gives early movers an insurmountable lead in production capability and therefore cost of production, and causes them to survive the shakeout stage of the industry lifecycle at much higher rates than later entrants.

We extend Klepper’s basic model in the following way. We argue that the production capabilities that early mover develop early in the industry lifecycle are not only superior to the capabilities of rivals that enter later; they’re often superior to those of many existing suppliers. This is because early experience with the production of a product can often applied to the fabrication of certain product components as well, and because the supplier base for a new industry requiring new types pf components is likely to be thin early on, early movers are more likely to be backward integrate into component production. As Langlois and Robertson (1989) explain, many early entrants into the automobile industry began as vertically disintegrated assemblers – buying auto components from suppliers, some of whom, in the early period, were simply adapting components from bicycles or carriages (their main output markets) to automobiles. As automobile designs developed and became more technically complex, however, components became more automobile-specific. In addition, as assemblers gained production experience, those experiences produced knowledge useful for the fabrication of components. Langlois and Robertson (1996) describe the case of Ford Motor
Company as one in which the firm increasingly pursued vertical integration during the 1920’s because it had developed superior capabilities in certain kinds of machine tools useful for component fabrication (pp. 52-53). Thus, because a supplier base for more auto-specific components had yet to fully emerge in the early period, and because more experienced assemblers began to apply their experience in assembly to component fabrication, we hypothesize that early movers were more vertically integrated than later entrants.

**H3a. Early entrants will vertically integrate into a broader range of components than later entrants.**

A key aspect of Klepper’s (1996) model of the industry lifecycle is that some early entrants do not compete primarily on their production capabilities and therefore cost of production, but instead compete by offering innovative product designs for which they earn premium prices. In his model, this latter strategy is viable early in the pre-shakeout stage of the industry lifecycle, before the product becomes standardized and competition begins to occur primarily on process innovation and therefore cost of production. Such early differentiators, because they do not produce at high volume, never develop superior production capabilities, so that even though they enjoy average rates of survival in the early stages of industry evolution, they fail at higher rates during the shakeout stage. The implication is that early entrance may not be a strong indicator of a firm’s actual production capabilities. A more precise measure would be the extent of a firm’s actual production experience early in the industry. We therefore hypothesize that:

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6 Another disadvantage of relying solely on firm age as a proxy for firm production capability is that older firms may also be more inertial (e.g., Hannan and Freeman 1984). Inertia might make older firms slower to vertically disintegrate as the dominant design emerges. Because this kind of effect operates in the same
**H3b.** Firms with more production experience early in the emergence of an industry will be vertically integrated into a broader range of components than firms with less early production experience.

**DATA**

Our database was constructed from a larger database that includes a range of information on auto companies and car components for virtually every firm in the U.S. auto industry during the period 1917-1931. The larger database was constructed from a variety of historical sources, especially Lester-Steele (1960); Georgano (1982); Baldwin, et al. (1987); Gunnell (19870; Kimes & Clark (1989) and Flammang & Kowalke (1989). Each of these sources represents the culmination of many years of research by historians, journalists, collectors and others. Parts of the database have been analyzed by Carroll and colleagues (e.g., Carroll, Bigelow, Tsai and Seidel 1996; Dobrev, Kim and Carroll 2002; Dobrev and Carroll 2003). The information we use for the current analysis includes yearly data on firm age, firm size measured by sales, number of car models produced, whether a firm entered from a related or unrelated industry, vertical integration (or not) of nine different automobile components and auto prices. Auto prices were available for 68% of the car models listed in Kimes & Clark (1989), the definitive reference thought to capture information on every auto company that has operated the U.S. Car prices come from Lester-Steele (1960), and were available from 1917-1931. Vertical integration data was available for 31% of the firm model years in the larger database in the period 1920-12931. Our final sample size consisted of 455 firm year observations that span the period 1920-1931.

direction as the dominant design effect hypothesized above, the two effects would be difficult to distinguish empirically using firm age alone as the only proxy for production capability.
To measure vertical integration, we gathered information on whether each of the following nine major car components was made or bought for each of the car models produced by a given firm in a given year: rear axle, clutch, carburetor, transmission, body, frame, engine, steering, and ignition. We relied especially on Lester-Steele (1960) for this data. If a given component was produced internally, we coded a 1 for that component in that year, otherwise, we coded a zero. We then created a vertical integration measure for each firm in each year by summing these values for each firm-year and dividing by the number of car models produced by the firm in that year.7

MODEL SPECIFICATION AND ESTIMATION

We estimated regression models featuring the degree of vertical integration (VERTICAL INTEGRATION) as the dependent variable. Our first independent variable of interest in these regressions was a dummy variable, “POST 1925”, that takes the value of 1 for the years 1925-1931 and 0 otherwise, thus controlling for the years before and after the midpoint of our sample period 1920-1931. Hypothesis H1 led us to expect a negative and significant coefficient estimate for this variable, since the emergence of the dominant design or product standardization in autos during the period covered by our data implies, following the industry lifecycle and transaction cost literatures, progressively less vertical integration in general. The literature on dominant designs has emphasized that the dominant design in automobiles began to become established during the mid-1920’s, since the all steel closed body had largely diffused by this time.

7 In an alternate specification, we entered the number of models on the right hand side of our regression estimations rather using it as the denominator of the dependent variable. This alternate approach did not change our results. In only a few cases in our data did a firm make a certain kind of component for one car model, but buy that type of component for another model. Those few cases were coded with a value of .5 for the component in question.
(Abernathy 1978). In some studies, the actual year taken as the year in which the dominant design became established is 1923 (e.g., Suarez and Utterback 1995), and in a separate specification we replaced our “POST 1925” dummy variable with a corresponding “POST 1923” dummy variable. Because there may be lags in the process by which firms vertically disintegrate as a dominant design emerges, our expectation is that the POST 1925 variable will show a stronger negative effect on vertical integration. For example, Argyres and Liebeskind (1999) argue that what they call “governance inseparability constraints” can delay a firm’s attempts to vertically disintegrate in a way consistent with economizing on transaction costs. In their study of vertical disintegration as a response to trucking regulation in the U.S. in the 1980’s, Nickerson and Silverman (1993) found evidence consistent with the operation of such constraints.

Our second independent variable of interest was AVERAGE PRICE, which represents the price charged by a firm in each year. For companies producing multiple models in a given year, we used the average of the firm’s model year prices to proxy for the firm’s competitive positioning. We expect a positive and significant sign on this variable’s coefficient estimate, because, as we argued based on industry lifecycle and transaction cost theories, greater premium pricing based on component level differentiation requires more model-specific components and hence tends to lead to greater vertical integration.

Our third independent variable of interest is firm age (AGE), measured from the time of entry into the industry. Recall that Klepper and colleagues have found that early movers tend to develop superior production capabilities relative to later entrants, which account for their greater long run survival chances. We argued that this superiority
extends to suppliers, and therefore we expect a positive and significant sign on this variable. As an alternative, however, we included another proxy for firm production capability, EARLY SALES. This variable is measured as the sum of the firm’s yearly sales figures from 1917-1920, the three years leading up to our sample period. The idea here is that firms that achieved higher levels of sales earlier in the period where able to gain greater production experience due the greater production they engaged in. Following Klepper and colleagues, this experience led them to develop superior capabilities that even large later entrants were not able to match. Once again, firms with superior production capabilities relative to rivals tend to have superior capabilities relative to suppliers as well (particular early in an industry’s development), which leads us to expect a positive and significant sign on the coefficient on EARLY SALES.

Make-or-buy studies in the transaction cost literature often do not control for possible effects of demand uncertainty on make-or-buy choices, even though Harrigan (1983) argued that such effects can be important. In part this lack of interest in demand uncertainty is due to Carlton’s (1979) seminal article, in which he showed that there is an incentive to backward integrate only when the demand for final products is uncorrelated with the demand for inputs into those products. This lack of correlation only occurs when suppliers sell inputs that are so generic that they are sold into multiple output markets. The data with which we measure vertical integration in this study, for example, includes components that are sold only to the auto industry, so that no effects from demand

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8 We replaced our EARLY SALES measure with one that measured cumulative sales from 1917-1923, with no change in the results.
9 In unreported regressions, we entered the log of annual firm sales (FIRM SIZE) as an additional control variable. Our results did not change with this addition. We do not report these regressions because transaction cost theory suggests that any effects of economies of scale on vertical integration should operate through transaction cost variables like asset specificity (e.g., Williamson 1975; Riordan and Williamson), for which we already proxy with our POST 1925 and AVERAGE PRICE variables. In addition, FIRM SIZE is highly correlated with EARLY SALES (\(\rho=0.87\)), which inflates the standard errors.
uncertainty on vertical integration would be expected according to Carlton’s (1979) model. A recent model by Kranton and Minehart (2000), however, shows how demand uncertainty can matter for vertical integration even when output and input demands are correlated. They show that when firms face idiosyncratic, firm-specific demand shocks, rather than demand shocks that affect the entire industry equally (the setting that Carlton 1979 had studied), then firms can have an incentive to maintain flexibility by relying on a network of multiple external suppliers (who are not under long term contract), rather than engaging in vertical integration.

To control for possible effects of firm-specific demand uncertainty on vertical integration, we constructed a variable, DEMAND UNCERTAINTY, for each firm year. Similar to Lieberman (1991), we constructed the variable by first running an OLS regression of FIRM SIZE measured by annual sales (representing firm-specific demand in any year) on TIMECLOCK and TIMECLOCK², then taking the residuals of this regression as our DEMAND UNCERTAINTY variable. TIMECLOCK takes a value between 1 and 11 for each year between 1920 and 1931. This method serves to isolate that portion of the demand for a given firm’s products in a given year that is not due to a trend in firm-specific demand, but rather represents shocks. Lieberman (1991) used this detrending approach to measure industry-level demand uncertainty in his study of the determinants of vertical integration in chemical processing.

**Estimation**

As we noted earlier, the dataset on which we aim to test our hypotheses is a subset of a larger database that includes information on essentially the entire population of U.S. auto firms. Unfortunately, we do not have data on vertical integration and car prices for
every firm model year in the population database. Moreover, in collecting our data, we suspected that there might be a selection bias with regard to our final dataset, because information on smaller firms, and information from earlier in the period, seemed to be less available than information from larger firms, and from later in the period. Initial (unreported) logit regressions on the presence or absence of data on vertical integration and average price as a function of firm size, year effects, and other variables confirmed that our sample was indeed biased. Therefore, we could not rely on OLS to produce unbiased coefficient estimates.

In order to correct for our sample selection bias, we estimated Heckman two-step selection models (Heckman 1979). In the first step, the selection equation, we entered variables that appeared based on our data collection to affecting whether data on vertical integration appeared in our database or not. Because data from older and larger firms seemed to be more prevalent, we entered FIRM SIZE (logged due to skewness), FIRM AGE, and a variable representing the number of car models sold in any year (NUMBER OF MODELS). Because data on vertical integration was more prevalent later in the period, we also entered the TIMECLOCK variable. Finally, in order to identify our two-equation system, we entered a variable, DE ALIO, that seemed to be affecting the presence or absence of data on vertical integration, but was not correlated with vertical integration. DE ALIO is a dummy variable that takes the value of 1 if the firm entered the auto industry from a related industry (such as carriages or bicycles) and 0 if the firm entered de novo. We found no strong theoretical reason to think that de alio entrants would be more or less vertically integrated than de novo entrants, and indeed the correlation between DE ALIO status and vertical integration is very low ($\rho = .017$).
RESULTS

Table 1 shows descriptive statistics and correlations between our variables. We note that the explanatory variables of interest -- firm age, early sales, and average price -- are positively correlated with vertical integration. Table 2 presents the coefficient estimates from the Heckman two-step regressions. The estimates of the selection equation confirm the selection bias. The coefficients on FIRM AGE, FIRM SIZE, NUMBER OF MODELS and DE ALIO are all positive and significant, indicating that data on vertical integration was more likely to be available from the population of auto firms if a firm was older, larger, sold more models, and entered from a related industry. In addition, the coefficient on TIMECLOCK was positive and significant, indicating that data was more likely to be available for later years in the sample period.

Turning to the second step equation estimation, we note that the coefficient estimate on POST 1925 is negative and significant, as expected. This provides support for hypothesis H1; as a dominant design becomes established in the industry during the mid-1920’s, components become more standardized, and firms tend to vertically disintegrate in to order economize on transaction costs. The coefficient on AVERAGE PRICE is also positive and significant, providing support for H2. Firms that were attempting to differentiate themselves on some basis or other (speed, body style, comfort, safety, ease of use, etc.), and were charging higher prices due to those features, tended to produce more components themselves. Firms competing more on cost, producing more standardized cars at lower prices, tended to be less vertically integrated into component
production. Thus, we find evidence in support of our combination of lifecycle and transaction cost theories of vertical integration across the industry lifecycle.

Our two proxies for firm production capability, FIRM AGE and EARLY SALES, both carry positive and significant coefficient estimates, implying support for H3 and H4. Firms that entered earlier, and firms that were building up superior production capability just prior to the beginning early in the period, tended to be more vertically integrated, as they increasingly applied that capability to component production during the 1920’s and early 1930’s. Recall that these hypotheses were extensions of capabilities-based theories of firm boundaries (e.g., Demsetz 1988; Kogut and Zander 1992; Langlois 1992; Argyres 1996; Jacobides and Winter 2005), combined with lifecycle theory and the associated empirical findings of Klepper and colleagues (e.g., Klepper and Graddy 1990; Klepper 1996; Klepper 2002). Note from Table 1 that FIRM AGE and EARLY SALES are positively correlated, but not highly so, indicating that some early entrants did not succeed in developing superior production capability, at least as we are able to measure such capability. Early entrance, however, is associated with greater vertical integration for the average early entrant. Finally, note that the coefficient on DEMAND UNCERTAINTY is negative, as expected from Kranton and Minhart’s model (2000), but it is not significant.

Robustness

We ran several types of checks on the robustness of our results. The first was reported in footnote 7 above; we added a measure of the log FIRM SIZE as an additional control, with no change in our results. We do not report regressions with FIRM SIZE added because of the lack of theoretical relationship between size and vertical integration.
that is not already captured by our proxies for production experience (FIRM AGE, EARLY SALES) and (indirect) proxies for transaction costs (AVERAGE PRICE, POST 1925). Second, we re-estimated Model 1 excluding the three companies that later came to dominate the U.S. auto industry: General Motors, Ford and Chrysler. These three firms were much larger than their rivals during every year in our dataset, and were responsible for the high degree of skew in the distribution of firm size (skew=8.72). Our concern was that these giants might be driving certain of our results, such as the production capability effect we were finding on vertical integration. This concern proved to be unfounded, however. Excluding what later became the Big Three did not affect any of our results.

A third robustness check involved replacing our POST 1925 dummy with a POST 1923 dummy. Recall that previous authors have used 1923 as the year by which the dominant design had emerged in the auto industry. The possibility of lags in the vertical disintegration process, however, led us to expect vertical disintegration to occur somewhat later. Still, we report the results with the POST 1923 replacement in Table 2 as Model 2. Note that the competitive position effect and the production capability effect are as before with Model 1; the coefficient estimates on AVERAGE PRICE, FIRM AGE and EARLY sales remain positive and significant. The coefficient on the POST 1923 dummy, however, is positive and significant, not negative as we expected. This implies that the average firm was vertical integrating to a significant degree during the first three years of our sample period (1920-1923), so much so that the later vertical disintegration is overwhelmed. Note also that the coefficient estimate on DEMAND UNCERTAINTY remains negative, as expected, but becomes significant.
The results from the Model 1 estimation suggest to us that there are limits on the robustness of what we are interpreting as a dominant design effect on vertical integration. For example, if firms were for some reason “overshooting” the optimal degree of vertical integration during 1920-1923, perhaps the later vertical disintegration was simply a correction to this prior overshooting, not so much an effect from the dominant design becoming more established, along with the lags in vertical disintegration we discussed earlier. Or perhaps, overshooting correction and dominant design effects were combined. In any case, this robustness check found some limits on the robustness of the dominant design result, though but did not find limits on the competitive positioning and production capability results.

CONCLUDING DISCUSSION

Our results suggest evidence for three kinds of determinants of vertical integration over the industry lifecycle. First, we found evidence for a dominant design effect. As the dominant design became established during the 1920’s, automobile components became more standardized, which implied lower asset specificity in component transactions. Following transaction cost theory, firms efficiently reduced their levels of vertical integration. This effect, however, only occurred later in our sample period. Second, we found evidence for a competitive positioning effect. Once a dominant design becomes established, differentiation occurs on the level of individual components rather than overall product design. Firms attempting to compete by differentiating their products with enhanced components, and by charging higher prices, were more vertically integrated than firms competing on lower costs and lower prices. We suggest this was due to
differentiators economizing on transaction costs by vertically integrating the production of the key differentiating components due to their high asset specificity. Finally, we found evidence for a production capability effect. Early entrants into the industry, and firms that built up early production experience and therefore production capability, tended to be more vertically integrated than later entrants and less experienced firms. We suggest that firms with superior production capability sought to exploit it by applying that capability to components, in an early industry environment where suppliers were less capable than some (early entering) buyers.

Recent research on modularity is one area in which scholars have studied vertical integration/disintegration patterns as industries evolve (e.g., Langlois and Robertson 1989, 1995; Schilling and Steensma 2001). Langlois and Robertson (1995) point out that automobiles are not modular in the sense that consumers can recombine various components to semi-customize a car for themselves, in the way that can for personal computers or hi fidelity stereo systems. Autos have properties of modularity, at least from the auto assembler’s perspective, however, to the extent that their design is based on a set of standardized interfaces between components (e.g., Baldwin and Clark 2000; Garud and Kumaraswamy 1995). Standardized interfaces, then, allow for vertical disintegration by reducing communication and coordination costs, as well as hold-up risks (Argyres 1999; Baldwin and Clark 2000, Schilling and Steensma 2001).

Our finding of a dominant design effect is consistent with perspectives in the modularity literature, since increasing product modularity was generally associated with organizational modularity in our data. Our findings also suggest, however, that over the industry lifecycle, there can be countervailing effects on organizational modularity.
stemming from other factors. In particular, auto firms with differentiation strategies, and those with superior production capabilities, tended to increase, rather than decrease, their vertical integration as modularity rose, even if on average, vertical integration fell. Thus, understanding firm boundary choices requires analyzing multiple impacts.

A more subtle theoretical implication of our findings regards the relationship between changes in the firm’s environment, and changes in the characteristics of the firm’s transactions. Institutional economists such North (1990) and Teece (1986) argued that changes in the legal and regulatory structures within which firms operate has an important impact on the firm’s choice of its vertical boundaries. For example, stronger patent laws, by stimulating the market for inventions, reduces the incentive for vertical integration of R&D activities. Along these lines, it has been argued that policies aimed at reducing judicial corruption, by making contract enforcement by the courts less biased, can similarly cause firms to substitute markets for internalization of transactions (Mui 1999). Williamson (1991) offered that such changes in the institutional environment tend to affect the governance of transactions by acting as a “shift parameters” – i.e. changing the relative governance costs of one institutional arrangement (i.e. vertical integration or market governance) versus another. Our findings here suggest that not only legal and regulatory changes may act as shift parameters in Williamson’s (1991) framework, but technological evolution can act in such ways as well. In particular, there may be natural patterns of technological evolution -- especially as new technologies emerge -- that systematically impact the characteristics of firms’ transactions, and in turn cause temporal patterns in vertical integration behavior. The emergence of dominant designs may be one example of this kind of technological evolution, but there may be others as
well. In addition, there may be natural tendencies in the evolution of customer tastes, particularly as consumers gain experience with fundamentally new products. These changes could also impact the nature of transactions in systematic ways, and alter governance choices.

Recognizing these kinds of possibilities, and understanding the underlying impacts of technological and taste evolution on transaction features, can help make transaction cost economics more useful as a strategic management theory. This is because by understanding the determinants of transaction characteristics (rather than simply taking transaction characteristics as given), and how those characteristics can change as an industry evolves, firms can better forecast future changes in governance that they might need to make. Note that such forecasting is not very important if we assume that shifting a governance structure to increase efficiency is costless, and is achieved instantaneously. This has been the traditional assumption in TCE. If, on the other hand, adjustment costs are significant and governance inseparability is strong as, Argyres and Liebeskind (1999) and Nickerson and Silverman (2003) have discussed, and if firms can make mistakes in matching governance forms to transaction characteristics (Masten 1993) then such adjustments may require significant time and cost, in which case the ability to forecast the need for governance changes could be extremely valuable.

Future research should continue to explore the ways in which technological evolution might impact transaction characteristics, and thereby suggest the need for changes in governance. For example, perhaps there are other, different kinds of evolutionary patterns besides dominant design emergence that tend to be common in particular kinds of industries (e.g., Klepper 1997). Future research should examine the
relationships between features of these kinds of evolutionary patterns on the one hand, and transaction features and governance on the other. The importance for strategic management of understanding these kinds of relationships is clear.
References


Lester-Steele, D.1960. *Automobile Specifications 1915-1945*, Columbus, OH.


Figure 1: Entry, exit and density, U.S. Auto Industry to 1980
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<tr>
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### Table 2: Heckman Two-Step Estimation of Vertical Integration Models

(standard errors in parentheses)

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***p<.01; **p<.05; one-tailed test