An Empirical Evaluation of Factors Determining Vertical Integration in U.S. Food Manufacturing Industries

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ABSTRACT

Vertical integration has become an important business strategy among food manufacturers because it allows them to manage and customize their production according to consumer needs. Economic theory has shown that vertical integration may be induced by transaction costs, demand variability, market power motives, and other factors. This paper presents an index of forward vertical integration for U.S. food manufacturing industries and uses an econometric analysis to examine the factors that motivate vertical integration in these industries. Empirical results indicate the role of both transaction cost factors and potential monopoly motives. [JEL Classification: L13, Q13.] © 2005 Wiley Periodicals, Inc.

1. INTRODUCTION

As the U.S. food system becomes more and more consumer driven, vertical coordination as a business strategy, either through ownership integration or through contracts, has become increasingly important. This is because vertical coordination allows both farmers and food manufacturers to manage and customize their production according to market needs. It is believed that vertical coordination has resulted in improved, consistently higher quality, more uniform food products, and more choices of food products for consumers. There are many studies that examine vertical coordination in the U.S. food industries since the early 1960s. These studies focus on the vertical relationship between the value-added food industries (i.e., food manufacturers) and the upstream production agriculture (i.e., farmers), e.g., Frank and Henderson (1992), Barkema (1994), O'Brian (1994), and Martinez (1999), among others.

Past studies have shown that, among the food industries, the poultry industry has been vertically integrated since the early 1960s, while vertical coordination has been spreading rapidly since the early 1980s into other food industries. For example, the percent of total production under ownership integration and contracts during the early 1990s in the poultry industry was 100%; in the processed vegetables industry, 98%; in the processed

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milk industry, 26%; in the meat packing industry, 16%; in the hog industries, 21% (O'Brian, 1994; Perry, Banker, Morehart, & Johnson, 1996); and the trend is continuing. The estimates provided by the existing studies are very similar and the general finding is that spot market transactions have been gradually replaced by some form of vertical coordination (mostly by contracts vis-à-vis vertical ownership integration).

Most of the reasons that firms choose to vertically integrate have to do with reducing costs or eliminating externalities that are associated with buying from or selling to other firms (Carlton & Perloff, 1999, Chapter 12). Economic theory has shown that vertical integration may be induced by transaction costs, market imperfections, and other factors.[1] For instance, a food processor may also be engaged in wholesaling operations thereby reducing or eliminating the transaction costs associated with writing and enforcing contracts with independent wholesalers. A firm that vertically integrates may also have monopoly motives, i.e., it may vertically integrate "to better exploit or create market power," or a firm that faces market power by another firm "may vertically integrate to eliminate that power" (Carlton & Perloff, 1999, p. 379).

While there have been several studies focusing on the motives for vertical integration in non-food sectors, to our knowledge no study other than Frank and Henderson (1992) quantitatively addresses the issue of motives for vertical coordination (or integration) in the U.S. food industries. Among existing studies, some are focused on the process and implications of vertical integration (or coordination) in a particular food industry, such as pork, beef, or broiler (e.g., Martinez, 1999; Rhodes, 1995). Others have focused on either the descriptive and/or theoretical explanation of vertical organization in the food industries (e.g., Boehlje & Schrader, 1998; Cotterill, 2001), or on the efficiencies of alternative vertical mechanisms, or the impact of vertical integration on market performance (e.g., Azzam, 1996; Bhuyan, 2002; Kinnucan & Nelson, 1993). On the other hand, Frank and Henderson (1992) empirically examined the effects of transaction cost factors on upstream or backward vertical coordination (via ownership or otherwise) between food manufacturers and their raw material suppliers or farmers. They found a positive relationship between transaction costs and vertical coordination via contracts. Empirical studies focusing on non-food sectors also report transaction cost linkages to vertical coordination (ownership or contracts), e.g., Levy (1985), Martin (1986), Caves and Bradburd (1988), and Lieberman (1991).

In this study, our aim is to examine the motives for vertical ownership integration (vertical mergers) in the U.S. food manufacturing industries.[2] There are two specific objectives of this study, first, to construct an index of vertical integration for U.S. food manufacturing industries, and second, to test the motives for vertical integration in these food industries. Our aim is modest in scope compared to Frank and Henderson (1992) because we are looking only at on one type of vertical coordination (i.e., ownership integration) and leaving out such scenarios as coordination via production or marketing con-

[1]See Perry (1989) for an excellent review of the vertical integration literature. Note that some of the motives for mergers found in the literature, e.g., empire building, managerial hubris, etc., are generally cited in the context of horizontal mergers.

[2]According to the traditional view, as in Carlton and Perloff (1999, Chapter 12), vertical (ownership) integration means the merger of two or more firms operating at different stages in a production-marketing process. For instance, when a food processor owns wholesaling operations and most of that food processor's integrated shipments went to the final market through company owned wholesale and/or sales office establishments, such shipments went through a vertically merged stage. As the analytical framework would show, we followed the current literature to empirically implement this more traditional definition of vertical integration.

tracts. Additionally, the focus here is *only* on the downstream or forward vertical integration in the U.S. food manufacturing industries into further processing, wholesaling, and retailing. Given the general objective of this study, it can be considered complementary to the Frank and Henderson (1992) study, although the latter was more comprehensive.[3] Our results suggest that transaction cost factors as indicated by managerial diseconomies and potential monopoly motives as indicated by the fewness of sellers, were mainly responsible for forward vertical integration in U.S. food manufacturing industries.

2. FRAMEWORK FOR ANALYSIS

The analytical framework is divided into two parts, first, we present the methodology behind the measurement of the vertical integration index, followed by an economic model to test the hypotheses for transaction cost motives for vertical integration in the U.S. food manufacturing industries.

2.1 Measurement of Vertical Integration Index

2.1.1 Background. Difficulty in measuring the degree of vertical ownership integration is well known (Caves & Bradburd, 1988, p. 265; Hay & Morris, 1991, p. 345). Such measuring difficulties obviously pose serious problems in attempts to analyze the impact of vertical ownership integration in the U.S. food manufacturing industries. Adelman's (1955) seminal methodology on the empirical measurement of vertical integration was modified and improved by Maddigan (1981) who relied on the national input–output (I–O) tables. Maddigan's "vertical industry connection index" for a given firm was based on the extent of technological relatedness, as revealed by I–O tables, among the set of industries within which the firm operates. That is, Maddigan's index specified industries within which a firm operates and incorporated vertical interdependencies revealed by I–O tables. Her index captured all backward and forward linkages that a firm had in the production-distribution chain.

Improving on the Maddigan index of vertical connection, Frank and Henderson (1992) developed a vertical coordination index to analyze various forms of upstream vertical ties, such as spot market transactions, supply contracts, and ownership integration that existed in the U.S. food manufacturing sector. This vertical coordination index represented the degree of backward vertical coordination that existed between U.S. food manufacturers (e.g., cheese manufacturers) and the suppliers of raw agricultural produce (e.g., dairy farmers). Frank and Henderson's (1992) vertical coordination index ranged from zero for spot markets to one hundred percent for complete backward vertical ownership integration. Using 1982 input–output data at the four-digit SIC (standard industrial classification) level, they found that the average vertical coordination index for food manu-

[3]While Frank and Henderson (1992) examined various types of backward vertical coordination (including vertical ownership integration or vertical mergers) in light of the transaction cost theory, this study is looking only at the forward vertical mergers. Both studies, however, construct indices of vertical coordination (or integration) for the U.S. food manufacturing industries and use econometric analysis to test hypotheses regarding motives behind vertical integration. In terms of comparison of the FVI index presented in this study with that of Frank and Henderson (1992), only limited comparison can be made because the FVI here can only be compared to Frank and Henderson's backward ownership integration index (called "Integration" in their Table 1 and "VI" in Table 3) and not to any other indices (i.e., not to the four vertical coordination indices in Frank and Henderson, namely VC1 through VC4).

facturing industries was 0.47, i.e., on average the degree of backward vertical coordination between U.S. farms and food manufacturers was almost at the mid-point on a scale with fully independent farms on one end and fully integrated farms (with food manufacturers) on the other end.

The vertical integration index presented here is based on the one developed by Davies and Morris (1995) which is also related to the work of Caves and Bradburd (1988). The Davies and Morris index was based on the simple notion that vertical integration is revealed by larger internal flows of output (i.e., output flows that take place within a firm's different plants in successive stages of production and distribution) as a substitute for market transactions. Therefore, intra-firm integration is incorporated in the measurement of vertical integration. MacDonald (1985) was the first to measure intra-firm linkages as the proportions of shipments from an industry that are made to (or bought from) affiliated units in another industry at a success stage in the production and distribution chain. For instance, in the case of downstream or forward successive stages, such affiliated units may include plants that perform further processing, sales offices, wholesale, and retail establishments (and would include input suppliers in the case of upstream or backward successive stages). Note that examining the reasons firms choose different strategies to vertically integrate downstream or use different wholesaling strategies is beyond the scope of this study.[4]

The essence of vertical integration is the decision by the individual firm to organize exchanges internally (within the firm) or externally (in the marketplace). In the food industries, for instance, while some industries rely almost exclusively on an independent wholesaling network (e.g., malt beverages such as whisky), others rely extensively on their own establishments (e.g., bakeries). However, because it is difficult, if not impossible, to obtain information on the internal and market exchange of individual firms (Perry, 1989). Therefore, the vertical integration index presented here (as in Davies and Morris, 1995) provides a more practical but perhaps theoretically less refined working definition of a vertical integration index for an industry.

2.1.2 Computation of the FVI index using the Davies and Morris method.

Although the vertical integration index proposed by Davies and Morris (1995) (and presented in Equation (1) below) was designed to utilize input-output accounting data, their methodology also allowed, at least in the case of the United States, the use of the *Distribution of Sales by Class of Customers* data (published by the U.S. Bureau of Census every 10 years). In their article, Davies and Morris (1995, p. 155) stated that the "key data ingredient," the intra-industry flows across industries, is rarely available in published form except for the U.S. in the form of *Distribution of Sales by Class of Customer*. We thus take advantage of this publicly available data to construct a FVI index for the U.S. food manufacturing industries.[5]

The procedure for the FVI construction is as follows: in an economy comprised of N firms and R industries, the extent of forward vertical integration in industry j is measured

[4]See Cotterill (2001) for a discussion on a topic related to this issue.

[5]Davies and Morris (1995) proposed a simple procedure for imputing the "intra-industry flows" from the "inter-industry flows" published by most countries, including the U.S., in the form of national input–output tables (Davies & Morris, 1995, p. 156). That procedure is explained in detail on pages 154–158 in the Davies and Morris article. It shows that the FVI index can be computed using both the *Distribution of Sales by Class of Customer* data and input–output data.

by the proportion of industry sales accounted for by the intra-firm flows of output from firms in that industry to their plants in other industries downstream, i.e.,

$$FVI_j = \sum_{\substack{k=1 \\ k \neq j}}^{R} \sum_{i=1}^{N} \frac{X_{j,k}^{i}}{X_j}, \tag{1}$$

where FVI_j is the index of forward vertical integration of industry j, $X_{j,k}^{i}$ is the total flow of output from firm i from its plants in industry j to its plants in industry k, and X_j is the total sales of industry j. If there are no intra-firm flows between industry j and k, then $\mathrm{FVI}_j = 0$, indicating the lack of a measurable level of vertical ownership integration (given data and methodological constraints). Similarly, if industry j is fully integrated to downstream industry k, then $\mathrm{FVI}_j = 1$. Thus, the value of the forward vertical integration will lie between 0 and 1 or $0 \leq \mathrm{FVI}_j \leq 1$.

Using the *Distribution of Sales by Class of Customer* data, we construct an index of forward vertical ownership integration (see explanation later) where a food manufacturing firm i in industry j owns plants or firms in another industry k ($j \neq k$), where k may include wholesaler, retailers, or other downstream food manufacturers. Such measurement reflects ownership integration between both business units in a given industry and those in industries downstream from it, thereby offering the potential for testing the transaction cost hypotheses on such vertical relationships. Note that such a measurement will miss any integrated enterprises that operate in vertically related industries but do not actually transfer intermediate products between their units (Caves & Bradburd, 1988).

Some of the features of this vertical ownership integration index are as follows: (a) it is based on the explicit notion of what constitutes vertical ownership integration, (b) this index can be computed using public domain data, and (c) this index can be calculated at either the firm or the industry level or both. However, as Perry (1989) noted, it is almost impossible to find firm level data and not surprisingly we use industry level data in this study. Note that the vertical integration index, FVI_j, does not reveal which party initiated the integration.

2.2 Determinants of Vertical Integration

2.2.1 Fewness of sellers and Asset specificity. Among various reasons for vertical integration, one of the most important reasons firms integrate has to do with transaction costs, and the inducement for vertical integration rises as the transaction cost of using the marketplace rises (Klein, Crawford, & Alchian, 1978; Williamson, 1974, 1975, 1986). According to the transaction cost theory, vertical integration is induced by the problems of small-numbers bargaining and asset specificity. Such problems can arise either due to small number of firms in the market, *ex ante*, or due to transaction-specific assets and switching costs that create lock-in problems, *ex post*. In the former case, fewness of buyers and sellers should positively predict vertical integration as firms may utilize ownership integration to reduce the potential opportunistic behavior when few firms bargain (Caves & Bradburd, 1988). In the latter case, each party to the transaction has the potential to expropriate quasi-rents derived from the other firm's investment and if long-term contracts cannot be written to avoid potential hold-up problems, firms must resort to integration (Lieberman, 1991).

The evidence to support the hypothesis that vertical integration rises with supplying industry market concentration, representing fewness of sellers, has been obtained in various prior studies (e.g., Caves & Bradburd, 1988; Levy, 1985; MacDonald, 1985; Martin, 1986). In terms of food industries, Frank and Henderson (1992) find supporting evidence for backward vertical integration in the U.S. food manufacturing industries. Such findings are consistent with the argument that the small-numbers bargaining problem induces vertical integration and we hypothesize as such. A competing hypothesis, however, is that "fewness of sellers (buyers)" may also indicate a monopoly motive for vertical integration.

We also hypothesize that forward vertical integration is more likely when the upstream industry must commit to large sunk investments in assets. In this regard, the importance of an investment in specific human capital as an incentive to integrate vertically was emphasized by both Masten, Meehan, & Snyder (1989) and Caves & Bradburd (1988). For example, Caves and Bradburd found that vertical integration rises with spending on research and development, which was used as a measure of investment in highly specific human capital. Frank and Henderson's (1992) study arrives at a similar conclusion.

Regarding testing the motives for vertical integration in the U.S. food manufacturing industries, we use the four-firm concentration ratio (CR4) to capture the fewness of sellers because it is the most accepted and traditional measure of market concentration (Rogers, 2001). As one reviewer pointed out, some of the food industries which show lower i have a more relevant local or regional market rather than a national market, e.g., fluid milk, and in such cases the national concentration data may not be relevant. Although local or regional concentration data for food manufacturing industries is not available, given the fact that a single milk processor is able to supply a large retail market or Metropolitan Statistical Area, or a single feed mill is able to supply to hundreds of feedlot operators and/or ranchers, it is likely that such industries have high local/regional concentration. Therefore, we extend the "fewness of sellers" hypothesis to those food manufacturing industries which are more "local" or "regional" in nature. We use a locational dummy variable (LOCDUM, where 1 = local and 0 = otherwise) to represent these local/regional industries, such as fluid milk, ice cream, prepared feeds, among others, e.g., LOCDUM for fluid milk or SIC 2026 would be equal to 1, and so on. We expect a positive and significant impact of LOCDUM on the vertical integration index, FVI.

To capture the "lock-in" problem in terms of asset specificity in these industries, we consider the capital that is potentially sunk and specific to an industry. Following previous studies, such as Caves and Bradburd (1988), we use the food manufacturing industry's assets-to-employee ratio (EMPASS) and research and development intensity, i.e., R&D expenditures-to-sales ratio (RND), to capture such lock-in effects. Frank and Henderson (1992), for instance, call such variables "idiosyncratic investments" that capture differential characteristics and the asset specificity of a cross-section of food manufacturing industries. Higher asset specificity would increase the lock-in effect and would provide an incentive for vertical integration in the food industries.

2.2.2 Diseconomies of scale. Williamson (1974, pp. 1443–1456) points to diseconomies of scale as a factor limiting the extent of vertical integration. This is because the same transactional inefficiency factors promoting vertical coordination also limit the extent of internalization (Frank and Henderson, 1992, p. 947). Both Martin (1986) and Scherer and Ross (1990) note possible unfavorable impacts of such diseconomies on vertical integration. Following the literature, we employ two variables to capture such diseconomies of scale in the U.S. food manufacturing industries: (1) average firm size (AVFMSZ), measured as the average sales (in millions of dollars) per firm in an industry;[6] and (2) operational diseconomies (OPRDIS), measured as the average number of plants per firm in an industry. The first variable was used to capture the potential loss of managerial control, *ceteris paribus*, in large firms (in terms of sales). The second variable was based on the grounds that the cost of handling transactions within a firm should be greater, *ceteris paribus*, the larger the number of plants per firm. Thus, the predicted effect of these two variables, based on transaction cost theory on vertical integration in the food manufacturing industries, is negative.

2.2.3 Uncertainty. Market uncertainty regarding demand (or supply) makes it very costly or impossible for firms to anticipate all contingencies and induce firms to rely more on nonmarket coordinating methods, including vertical integration (Frank and Henderson, 1992, p. 946). According to Lieberman, although demand fluctuations alone are not sufficient to induce vertical integration, several studies have shown that vertical integration can be induced by uncertainty in demand or fluctuations in demand. For example, Carlton (1979) has proposed that firms integrate (or may rely on nonmarket coordination methods) to minimize the total costs attributable to demand fluctuations. To measure the fluctuation of downstream demand for food manufacturers' output, a coefficient of variation was computed for each industry using industry shipment data between 1982 and 1992. This measure of relative dispersion was used to represent the fluctuation in demand for food industry output (DEMFLUC). We hypothesize that food manufacturers are motivated to use vertical integration as a business strategy to rectify demand uncertainty in their output markets.

2.2.4 Bias Control. Finally, like its predecessors, this is an industry-level study (mainly due to data limitations) and therefore, likely to have some integration and aggregation bias. Following Davies and Morris (1995), we hypothesize that such aggregation bias would have negative regression coefficients. To correct for such potential bias, we use two control variables: (1) the number of five digit industries (5DIGIT) covered by each food manufacturing industry under study, and (2) the proportion of total industry sales accounted for by sales within the industry (INTRA), e.g., the value of shipment in the meat packing industry (SIC 2011) that is accounted for by SIC 2011, as recorded in the input–output tables.

3. DATA AND ESTIMATION PROCEDURE

The focus of this study is on the U.S. food manufacturing industries at the Census four-digit industry group or SIC level. There were 49 food manufacturing industries at the four-digit SIC level in 1992, the last year of the availability of the necessary industry data at SIC level. The FVI was constructed using 1987 Census data due to the unavailability of appropriate data to construct that index for 1992 (see the Appendix for details). Census

[6]Although we followed the existing literature to use the AVFMSZ variable to represent managerial diseconomies of scale, one reviewer commented that this was a "negative" use of that variable. We, however, recognize the "positive" use of this variable given the link between firm size and technological advancement, i.e., *a la* Schumpeterian argument. However, for the purpose of this study this "positive" use of the AVFMSZ variable was not directly relevant and therefore was not emphasized (note that although the correlation between AVFMSZ and RND was positive, it was quite low at 0.208 as shown in Appendix Table A2).

data on vertical ownership was not available for six industries and it prevented us from constructing the FVI index for those six industries: SICs 2043, 2062, 2068, 2076, 2085, and 2097. These six food manufacturing industries were dropped from this study and the remaining 43 were used.

Variable definitions along with their construction and data sources are provided in a data appendix (data available upon request). The definition of the FVI in the appendix also includes an example of how to construct the index using the meat packing industry (SIC 2011) data. We acknowledge that as in any empirical study, this study also suffers from data that do not perfectly represent the theoretical variables. But we concur with Frank and Henderson (1992) that "In the absence of conceptually desirable data, use of available data understanding true magnitudes should not diminish the underpinnings of [our] transaction cost and vertical coordination linkage estimates" (p. 946). The dependent variable FVI (bounded between 0 and 1) was transformed into the log-odds or logit functional form, ln[FVI/(1 − FVI)], for testing our hypotheses. Preliminary screening showed evidence of heteroscedasticity ($\chi^2_{9\,d.f.} = 18.518$). White's method was employed to obtain heteroscedasticity consistent estimates of standard errors (see SHAZAM, 1997, p. 83 for details). The overall fit of the model was acceptable for such a cross-sectional analysis (pseudo $R^2 = 0.298$).

A common criticism of the economic model presented here is that such models may have simultaneity bias and/or endogeneity bias because some of the explanatory variables (e.g., CR4 and RND) may be partially endogenous or simultaneously determined. Results of the Hausman tests for simultaneity and endogeneity (see Gujarati, 1995, p. 669–673 for details) rule out such bias. For example, results of the simultaneity tests show that residuals for both CR4 and RND were statistically not significant (absolute t values for these two variables were 1.007 and 0.582, respectively, with 33 degrees of freedom) and results of the endogeneity test for these two variables showed that the computed Wald chi-square statistic was statistically insignificant ($\chi^2_{2\,d.f.} = 3.145$). Summary statistics and a correlation matrix for the variables used in this study are presented in Appendix tables 3 and 4, respectively. The SHAZAM computer program was used to carry out all the econometric analyses, including the above mentioned tests.

4. EMPIRICAL RESULTS

This study examines the role of transaction costs and other factors on forward vertical integration in the U.S. food manufacturing industries. Using census data, an index of vertical integration was computed for 43 food manufacturing industries. That index was later used as the dependent variable to test hypotheses related to transaction costs. Given a possible maximum of 1.00 for the forward vertical integration index (or 100% ownership of a downstream stage in a vertical production-distribution chain by its upstream firms), results in Table 1 show that the degree of forward vertical ownership integration in U.S. food manufacturing industries was about 12%, which is quite low.

Table 1 shows that the forward vertical integration index value ranged from 0.010 in the wet corn milling industry (SIC 2046) to 0.3355 in the soft drinks industry (SIC 2086). This means that, while 33% of the shipments in the soft drinks industry go to the downstream firms that are owned by the soft drinks industry (e.g., Coca Cola owning its own wholesaling or retailing operations), only 1% of the shipments in the wet corn milling industry go downstream to firms owned by that industry. Some of the industries that show a larger downstream ownership include the bread and bakeries industry (SIC 2051; per-

TABLE 1. Degree of Vertical Integration in the U.S. Food Manufacturing Industries, 1992

SIC Code	Industry description	Forward Vertical Integration Index (FVI)
2011	Meat packing plants	0.1261
2013	Sausages and other prepared meats	0.2710
2015	Poultry slaughtering and processing	0.1623
2021	Creamery butter	0.2909
2022	Cheese, natural and processed	0.0584
2023	Dry, condensed, and evaporated dairy products	0.0511
2024	Ice cream and frozen desserts	0.2805
2026	Fluid milk	0.2697
2032	Canned Specialty	0.0546
2033	Canned fruits and Vegetables	0.0793
2034	Dehydrated Fruits, vegetables and soups	0.1846
2035	Pickles, sauces and salad dressing	0.0446
2037	Frozen fruits and vegetables	0.0541
2038	Frozen specialties, n.e.c.	0.0997
2041	Flour and other grain mill products	0.0210
2044	Rice milling	0.0505
2045	Prepared flour mixes and doughs	0.0269
2046	Wet corn milling	0.0100
2047	Dog and cat food	0.0516
2048	Prepared feeds, n.e.c.	0.2162
2051	Bread, cake, and related products	0.3275
2052	Cookies and crackers	0.0259
2053	Frozen bakery products, except bread	0.1269
2061	Raw cane sugar	0.0603
2063	Beet sugar	0.0954
2064	Candy and other confectionary products	0.0660
2066	Chocolate and cocoa products	0.0832
2067	Chewing gum	0.0765
2074	Cottonseed oil mills	0.0437
2075	Soybean oil mills	0.1399
2077	Animal and marine fats and oils	0.0792
2079	Edible fats and oils, n.e.c.	0.1564
2082	Malt beverages	0.0236
2083	Malt	0.0467
2084	Wines, brandy, and brandy spirits	0.0876
2086	Bottled and canned soft drinks	0.3355
2087	Flavoring extracts and syrups, n.e.c.	0.1866
2091	Canned and cured fish and seafoods	0.2112
2092	Fresh or frozen prepared fish	0.0797
2095	Roasted coffee	0.1652
2096	Potato chips and similar snacks	0.1370
2098	Macaroni and spaghetti	0.0866
2099	Food preparations, n.e.c.	0.1753
	Industry Average	0.1214
	Maximum	0.3355
	Minimum	0.0100
	Standard deviation	0.0893

Note. n.e.c. = not elsewhere classified.

TABLE 2. Determinants of Vertical Integration in U.S. Food Manufacturing Industries ($N = 43$)

		Model 1		Model 2	
Variable Name	Expected Sign	Estimated Coefficients (S.E.)[b]	Beta Coefficient[c]	Estimated Coefficients (S.E.)[b]	Beta Coefficient[c]
Industry Concentration (*CR4*)	positive	−0.011** (0.006)	2.22	−0.013** (0.005)	2.62
Location Dummy (*LOCDUM*)	positive	0.779** (0.359)	2.84	—	—
Research & Development Index (*RND*)	positive	0.168 (0.555)	0.35	0.408 (0.563)	0.84
Assets-Employee Ratio (*EMPASS*)	positive	−0.0005 (0.0003)	3.19	−0.0005 (0.0003)	3.19
Average Firm Size (*AVFMSZ*)	negative	−0.011* (0.006)	3.24	−0.009 (0.006)	2.65
Operational Diseconomies (*OPRDIS*)	negative	−0.593* (0.307)	3.01	−0.538* (0.301)	2.73
Demand Fluctuations (*DEMFLUC*)	positive	0.007* (0.004)	1.19	0.007* (0.004)	1.19
Integration and Aggregation bias 1 (*5DIGIT*)	negative	−0.019 (0.037)	0.58	−0.017 (0.043)	0.52
Integration and Aggregation bias 2 (*INTRA*)	negative	1370.8 (1391.0)	3.08	1406.3 (1409.0)	3.16
Constant		−0.587 (0.494)	—	−0.594 (0.519)	—
R^2 between observed and predicted		0.298		0.246	

Notes. Dependent variable = forward vertical migration (FVI).[a]
[a]logit transformed vertical integration index
[b]Heteroscadasticity-consistent estimates of standard errors (obtained using White's corrections) are in parenthesis.
[c]Beta coefficients are in absolute terms.
** significant at 95% level; * significant at 90% level.

haps due to a large number of bakeries selling their products in their own stores), dairy industries (e.g., SIC 202), and the sausages and other prepared meats industry (SIC 2013).[7]

The results of the economic model used to test the transaction cost hypotheses are presented in Table 2 in the form of two estimated models: Model 1 and Model 2. While Model 1 represents the full economic model discussed earlier and contains the LOCDUM variable, Model 2 does not contain the LOCDUM variable. In terms of the estimated results, the only other difference between these two estimated models is that the variable

[7]Although not presented here, the data used to construct this index reveal some additional information on vertical integration, such as which industry is more integrated into retailing vs. into wholesaling. For instance, both the 1987 *Census of Manufactures* and the 1992 I-O tables reveal that the number of food manufacturing industries integrated into wholesaling (e.g., all of SIC 201, 2023, 2034, 2067, 2082, and several others) was substantially higher than the number of food industries that integrated into retailing (e.g., SICs 2022, 2026, 2033, and 2064). For this reason, the computation of two separate FVI indices, one for integration into wholesaling and the other for integration into retailing, would have resulted in inadequate number of samples to carry out the econometric analysis presented here.

used to depict diseconomies of scale (AVFMSZ) is statistically not significant in Model 2, while the same variable is statistically significant in Model 1. The following discussion is based on results pertaining to Model 1.[8]

The estimated results provide partial support for both the small-numbers hypothesis and the asset specificity hypothesis as determinants of forward vertical integration in the U.S. food manufacturing industries. The significant negative influence of CR4, used to capture the fewness of sellers, runs counter to the *a priori* reasoning presented earlier, and to the results of Caves and Bradburd (1988) and MacDonald (1985).[9] This outcome rejects the small-numbers hypothesis, which predicts a tendency for firms to vertically merge when there, are few sellers (or buyers). This would imply that fewness of sellers in the U.S. food manufacturing industries did not trigger vertical integration, and firms in the successive stages of food manufacturing and firms downstream (i.e., wholesalers and retailers) were able to overcome the potential adverse effects of the transaction costs associated with the fewness of sellers. An alternative explanation is that if food manufacturing industries are integrating downstream to countervail buyers' power downstream, the negative CR4 coefficient may be reflecting the countervailing power motive for integration and not the transaction cost motive. Another alternative explanation is that the sample and study period used in this study simply do not support the small numbers hypothesis. It is also possible that sample does not contain a sufficient number of observations to support the null hypothesis (i.e., fewness of sellers would increase vertical integration) for the food manufacturing industries.

Part of the answer to the unexpected sign of CR4 may also lie with the nature of the concentration data which is aggregated at the four-digit SIC level for the entire United States, and may have an inherent downward bias. This reasoning is similar to that of Davies and Morris (1995) who also observed a negative and significant impact of market concentration on vertical integration. To counter the inherent downward bias of national concentration data, we used a locational dummy (LOCDUM) to represent those food manufacturing industries which could be considered as more "local/regional" in nature. Not surprisingly perhaps, the coefficient of the LOCDUM variable was positive and significant, i.e., the fewness of sellers at the local or regional level do seem to support the transaction cost hypothesis. Or could there be an alternative explanation for the sign and significance of the coefficient of the LOCDUM variable? If the local/regional concentration is high, food manufacturing firms with local or regional market power may vertically integrate "to better exploit or create market power" (Carlton & Perloff, 1999, p. 379), i.e., there could be a monopoly motive explanation and not transaction cost explanation for the positive and statistically significant sign of the coefficient of the LOCDUM variable.

Among the variables used to represent the lock-in effects in terms of asset specificity (RND and EMPASS) and diseconomies of scale (AVFMSZ and OPRDIS), only those depicting diseconomies of scale appear with their expected signs and were statistically significant. Unlike Frank and Henderson (1992) who found that higher asset specificity provides an incentive for backward vertical integration in the U.S. food manufacturing industries, our results fail to show that higher asset specificity provides an incentive for forward vertical integration in these industries. On the other hand, estimated results show

[8]The OLS estimates of Models 1 and 2 (without heteroscedastic error correction) are available from the author upon request. They show that White's heteroscedasticity error correction improved the estimation.

[9]Use of the Herfindhal-Hirschman index (HHI) of industry concentration instead of CR4 did not fundamentally alter our results.

that the incentive for vertical integration is negated by strong diseconomies of scale, supporting arguments by Williamson and others' (e.g., Martin, 1986; Scherer & Ross, 1990) that diseconomies of scale could be a factor limiting the extent of vertical integration.

The demand fluctuation variable (DEMFLUC) used to test the uncertainty hypothesis appears with the expected sign and was statistically significant. This finding supports the hypothesis that food manufacturers are motivated to use vertical integration as a business strategy to rectify demand uncertainty in their output markets. In this regard, we acknowledge that demand fluctuations alone are not sufficient to induce vertical integration. Although Model 1 in Table 2 detects some aggregation bias, i.e., the coefficient of the variable 5DIGIT has the expected sign, such an effect was statistically not different from zero and therefore, is ignored. The beta coefficients[10] (Table 2, fourth column) show that among the variables with statistically significant coefficients, the following are in descending order of importance regarding their ability of explaining forward vertical integration in the U.S. food manufacturing sector: average firm size (AVFMSZ), operational diseconomies (OPRDIS), locational dummy to depict local/regional concentration (LOCDUM), industry concentration (CR4), and demand fluctuation (DEMFLUC). While most of these variables could be considered as transaction cost factors, we have established earlier that both LOCDUM and CR4 could also be attributed to market power motives of food manufacturing firms.

5. CONCLUSIONS

Testing hypotheses about vertical integration on cross-sections of industries "is attractive for the variance it supplies in the structural determinants, and for the chance to observe entities in presumed long-run equilibrium" (Caves & Bradburd, 1988, p. 265). Additionally, such a vertical integration measure is appropriate for use in cross-sectional analysis because it focuses on inter-industry and intra-industry transactions and integration (Frank and Henderson, 1992, p. 950). We construct a measure of forward vertical ownership integration that takes intra-firm and inter-industry transactions into account. This theoretically crude but practically straightforward index was used to compute the extent of forward vertical integration between U.S. food manufacturers and their downstream industries, such as retail and wholesale. Unlike the backward vertical relationship between the U.S. food manufacturers and farmers, the extent of forward vertical integration in the food manufacturing industries was quite low. Such finding supports a common belief among economists that backward vertical ties in the U.S. food production–distribution chain are higher than the forward ties.

Using the index of vertical integration constructed, we tested several hypotheses that propose that transaction cost driven factors were the primary determinants of forward vertical integration in the U.S. food manufacturing industries. The results of this study indicate that some transaction cost factors, particularly related to diseconomies of scale, were responsible for forward vertical integration in the food industries. The relationship between market concentration (i.e., fewness of sellers) and vertical integration was not as clear. The study results seem to support both the small-numbers hypothesis (at the local/

[10]Beta coefficients show which variables contribute most to the regression by taking into account the effect of a typical or "equally likely" change in variables. The beta coefficients were calculated by multiplying the estimated coefficients by the standard deviation of each regressor and dividing by the standard deviation of the dependent variable.

regional level) as well as the market power hypothesis at both national and local/regional levels. Regarding the relative importance of factors that affect vertical integration U.S. food industries, the most important factor was operational diseconomies followed by the fewness of sellers/buyers and finally demand uncertainty.

While the results of this study are generally consistent with the existing empirical literature on the subject, there are several limitations to this study (and studies of a similar kind). As one reviewer noted, there are “natural limitations” to this kind of study, mostly due to limitations on data and the measurement of economic variables. This study was no exception. Variables on both sides of the estimated model are imperfect measures of their true economic variables and therefore may have biased the results. Although the results accord reasonably well with the existing empirical literature, it is also possible that the findings are specific to the food manufacturing industries and care should be taken in generalizing the results. Additionally, due to the limited nature of the scope of this study, we do not examine why firms choose different strategies to vertically integrate downstream or use different wholesaling strategies. A future research agenda includes overcoming some of the weaknesses and limitations of this study.

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APPENDIX: DESCRIPTION OF VARIABLES

Forward vertical index (FVI): Equation (1) is measured as follows using inter-industry sales data for the meat packing industry (SIC 2011): total shipments from companies in the meat packing industry to establishments owned by these same companies included \$4,132.93 million (or 8.195% of total revenue) to downstream wholesale establishments, \$193.097 million (0.3829%) to retail stores and outlets, \$1883.423 million (3.73%) to other owned manufacturing establishments, and \$151.15 million (0.30%) to other non-manufacturing establishments. Thus, the forward vertical integration index in the meat packing industry is $\mathrm{FVI}_j = 8.195 + 0.3829 + 3.73 + 0.30 = 12.6079\%$ or 0.1261 (as shown in Table 1, column 3). Similar computations were carried out for other food manufacturing industries and the results are reported in Table 1. The date source for FVI was the *1987 Census of Manufactures* (subject series), *Distribution of Sales by Class of Customers*. It was not possible to construct a FVI index using 1992 data because the *Distribution of Sales by Class of Customers* data is published once every 10 years, and the *1987 Census of Manufacturers* (subject series) was the last publication (published in 1992) that contained SIC-based information. Given that the model and analysis presented here is based on SIC-based definition of industries, the data choice was limited to using the most recent SIC-based data, and the most recent SIC-based *Distribution of Sales by Class of Customers* data was for 1987.

Industry concentration (CR4): Four-firm concentration ratio at the four-digit SIC level obtained from the *1992 Census of Manufactures: Industry Series* (final series).

Location dummy (LOCDUM): Defined as 1 = local, and 0 = otherwise, to represent those industries that are local/regional in nature. The following industries are identified as local/regional: SICs 2024, 2026, 2048, 2051, and 2086. This variable was used by Rogers (2001) who kindly provided this data.

Research & Development (RND): The R&D intensity is defined as the ratio of R&D expenditure by food manufacturing firms to their domestic sales in 1992. We are not aware of any data source at the four-digit level for these industries other than that of Pagoulatos and Sorensen (Table A1, 1986). According to their data, the average R&D intensity for the sample food industries was 0.314 or less than one half of one percent of total sales. Although the NSF (National Science Foundation) does not publish R&D data at the four-digit SIC level, a look at a recent NSF publication *Research and Development in Industry: 2000* by Raymond M. Wolfe (2003) shows that not much has changed since the article by Pagaoulatos and Sorensen, i.e., even in 1990s, the R&D expenditure as a percent of sales in food manufacturing industries has remained at less than one half of one percent (0.4% in table A-19 in Wolfe, 2003). Although R&D expenditure in some individual industries may have changed since 1986, say, in meat packing, given that the overall R&D intensity for the food industries has not changed much, we do not believe that the use of R&D intensity data from Pagoulatos and Sorensen compromised the outcome of this study.

Assets-Employee Ratio (EMPASS): Following the Census Bureau definition, "asset" is defined as gross book value of total assets at the end of the year. The variable "employee" is defined as the number of production workers in an industry. Data source is the *1992 Census of Manufactures: Industry Series* (final series).

Average Firm Size (AVFMSZ): This is defined as the average sales (in millions of dollars) per firm in an industry. Necessary data on industry sales and number of firms per industry were obtained from the *1992 Census of Manufactures: Industry Series* (final series).

Operational Diseconomies (OPRDIS): It is defined as the average number of plants per firm in an industry. Necessary data on number of plants per industry and number of firms per industry were obtained from the *1992 Census of Manufactures: Industry Series* (final series).

TABLE 3. Descriptive Statistics for Variables Used in Regression Analysis

Name	*N*	Mean	St. Dev.	Minimum	Maximum
FVI	43	0.121	0.089	0.010	0.336
CR4	43	47.953	17.934	19.000	90.000
LOCDUM	43	0.116	0.324	0.000	1.000
RND	43	0.314	0.183	0.0001	0.728
EMPASS	43	213.740	567.660	15.286	3786.700
AVFMSZ	43	27.659	26.226	5.245	138.140
OPRDIS	43	1.411	0.452	0.903	3.077
DEMFLUC	43	24.085	15.090	3.260	93.710
5DIGIT	43	4.256	2.735	1.000	12.000
INTRA	43	0.745E-04	0.154E-03	0.000	0.923E-03

Demand Fluctuations (DEMFLUC): It is the coefficient of variation of industry sales for sample industries for the following years: 1982 (adjusted to the 1987 SIC definition), 1987, and 1992. Necessary date came from the *Census of Manufactures: Industry Series* for respective years. In addition, the *Industrial Productivity Data* set available at the National Bureau of Economic Research (www.NBER.org) was used to verify the 1982 and 1987 sales data.

Integration and Aggregation bias1 (5DIGIT): It is the number of five-digit industries under each four-digit SIC. This number is obtained from the *1992 Census of Manufactures: Industry Series* (final series).

Integration and Aggregation bias2 (INTRA): It is defined as the proportion of total industry sales accounted for by sales within the industry, e.g., the value of shipment in the meat packing industry (SIC 2011) that is accounted for by SIC 2011. Data source for this variable is the *Benchmark Input–Output Accounts of the United States, 1992* (“use” tables).

TABLE 4. Correlation Matrix of Variables Used in Regression Analysis ($N = 43$)

FVI	1.000									
CR4	−0.405	1.000								
LOCDUM	0.408	−0.216	1.000							
RND	−0.147	0.302	0.088	1.000						
EMPASS	−0.177	0.229	−0.014	0.075	1.000					
AVFMSZ	−0.196	0.459	0.158	0.208	0.105	1.000				
OPRDIS	−0.255	0.236	−0.010	−0.033	0.136	0.395	1.000			
DEMFLUC	−0.183	0.019	−0.047	0.043	−0.194	0.043	−0.217	1.000		
5DIGIT	0.146	−0.336	0.261	−0.039	−0.158	−0.046	−0.091	0.007	1.000	
INTRA	−0.186	0.130	−0.124	−0.082	0.487	−0.007	0.355	−0.258	−0.155	1.000
	FVI	CR4	LOCDUM	RND	EMPASS	AVFMSZ	OPRDIS	DEMFLUC	5DIGIT	INTRA

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