ALGORITHMS FOR VERTICAL INTEGRATION INDICES

by

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INTRODUCTION

Vertical relationships among firms have been recognized as an important phenomenon in marketing for years. Most economists agree that the extent of vertical integration within a marketing channel can influence the normative performance of that channel. Despite the recognized importance of vertical integration as an aspect of structure, the preponderance of industrial organization effort has been directed to measurement of horizontal relationships among firms. This effort is manifest in measures such as concentration ratios, the Herfindahl index, Tall-Tideman index, and others. Systematic quantitative comparisons of vertical integration would be facilitated by an acceptable index, much like horizontal measures facilitate comparison of concentration.

The purpose of this manuscript is to suggest two algorithms for a vertical integration index. Before elucidation of algorithm specifics however, some perspective is necessary on the definition of vertical integration and unit of analysis.

Definitions

Vertical Integration

The concept of vertical integration can be complex. Although consensus exists that the concept involves combining stages or levels of production, differences exist on what constitutes a stage or level.

Gort addressed this problem (Gort, pp. 11-12):

> "Within every establishment, the same productive functions may be conceived of as a continuous process or, alternatively, subdivided into a vast number of separate operations, each of which may be identified as a separate stage in production."

Along a similar vein, Mighell and Jones offered a definition of stage (Mighell and Jones, p. 7):

> "As a working definition, we shall consider that an economic stage in production is any operating process capable of producing a salable product or service under appropriate circumstances. Such a process may be part of a larger production sequence within a firm so that no sale of the intermediate products occurs."

Trifon offers a review of the historical changes in conceptualization of integration and the definition of vertical integration which is adopted in this manuscript (Trifon, pp. 734-736):

> "... the ownership or control by one company of enterprises in different stages of production or distribution, where each stage yields a salable commodity" (Trifon, p. 736).

With both the definitions of Mighell-Jones and Trifon the concept of vertical integration becomes one of ownership integration, as contrasted to contractual integration sometimes referred to by other writers (Roy, pp. 1-6; Schneidau).

Throughout this manuscript, vertical integration is defined in terms of ownership or control of establishments at two or more levels in a marketing channel. Thus, integration means a particular state of firm organization within a marketing channel rather than the process or act

of integrating. Also, a dichotomy exists between interindustry and intraindustry vertical integration. If horizontally arrayed firms at a particular level within a marketing channel define an industry, then intraindustry vertical integration measurement involves the extent to which establisments at a particular level are related through ownership or control to firms at a different level in the same marketing channel. Interindustry vertical integration measurement would involve aggregation over industries within a marketing channel.

Unit of Analysis

In practical application of any measurement device the unit of analysis chosen has important consequences for the interpretation and comparability of measurement. At least three units of analysis could be appropriate for vertical integration measurement—industry, marketing channel segment, and subsector. Each unit represents increasing aggregation.

As previously mentioned, the notion of industry is a horizontal array of firms at a particular level in a marketing channel. Thus, an industry is composed of firms only on one side of a market or pricing point within a channel.[1/] Several studies have focused on the measurement of vertical integration for an industry.[2/] Such measures may provide useful information in regard to evaluating industry performance but add little to knowledge concerning market performance for an entire marketing channel or subsector.

Shaffer provides the definition of subsector as "the vertical set of activities in the production and distribution of a closely related set of commodities" (Shaffer, p.3). For example, the cattle-beef subsector

would include all firms from those engaged in cattle production (cow-calf producer) on through to those engaged in final sale of meat to consumers (be it at a restaurant table or meat counter of a retail store).

A marketing channel segment is composed of two or more vertically related industries within a subsector. The notion of segment is fluid, depending on the purpose of a particular analysis. Thus, for purposes of measuring vertical integration in the cattle-beef subsector, three channel segments might be defined. One segment could be for cattle: from cow-calf producer through to processor. Another could be the HRI meat segment from processor to HRI consumer. The third then would be the retail meat segment from processor to retail customer (at-home consumption). Each segment could be a meaningful analytic unit for the investigation of vertical integration and the evaluation of market performance.

For some commodities little may be gained from attempting to measure the extent of vertical integration of an entire subsector because interpretation difficulties may render such an aggregated measure meaningless. For example, consider the cotton-fiber subsector. The raw cotton segment is clearly from the cotton farmer through the textile milling industry. However, from this level to ultimate consumer a myriad of marketing channel segments for fiber (i.e. both cellulosic and non-cellulosic fibers) exist, each with unique end products. In this instance, it may be that the greatest level of meaningful aggregation which can be achieved is segment.

By definition, interindustry vertical integration measures would involve an aggregate analytic unit--either a marketing channel segment or a subsector. Normative performance implications for a marketing channel concerning vertical integration can flow only from aggregate measures. The two algorithms outlined in this manuscript presume a unit of analysis of either channel segment or subsector. The most appropriate of these analytic units depends upon the particular circumstances of application.

A Pricing Point Index

Definition

A naive temporal vertical integration index could be based on vertical pricing points within a marketing channel. Such an index would reflect the fact that as total vertical integration occurs over time in a particular channel pricing points disappear. That is, if a particular channel at time t has P pricing points and at time t+1 the entire channel has become totally integrated, then only one pricing point would remain (at the final consumption level). The change over time in number of pricing points may be formalized into an index by:

$$(1) \quad \psi_t = \Delta P / P_t - 1$$

where $0 \leq \psi_t < 1$ since $\Delta P = P_t - P_{t+1}$, $P_t \geq P_{t+1} \geq 1$ and P represents the integer number of vertical pricing points in a particular marketing channel at a particular time.[3/] ψ_t becomes an index measure of integration which has occurred between the base time period t and t+1.

For example, suppose at time t a marketing channel has six generally recognized pricing points and at time t+1 two pricing points within the

channel have become completely integrated ($P_{t+1} = 4$). Thus, $\psi_t = 0.4$. At some later period, t+2, suppose only three pricing points exist, so $\psi_t = 0.6$ using t as the base. The limits of ψ_t occur when no change in pricing points occurs between time periods (i.e. $\Delta P = 0$, $\psi_t = 0$) and when all pricing points but one have disappeared between time periods (i.e. $P_{t+1} = 1$, $\psi_t = 1.0$).

In some instances, parallel marketing channel segments may exist for the same commodity and could be considered simultaneously by computing a pricing point index weighted by the volume importance of each parallel segment. Suppose M parallel segments exist, each with V volume. Then,

$$(2) \quad \psi_t = \sum_{m=1}^{M} (\Delta P/P_t - 1)_m \, V_m$$

where $0 \leq V_m \leq 1.0$ and $\Sigma V_m = 1.0$. Thus, V_m could simply represent the percent of total volume which moves through segment m.

For illustrative purposes, suppose there are two parallel segements for a commodity (M=2) with the first segment representing 70% of the total volume. If the first segment from time t to t+1 diminishes by one pricing point from a base of six while the second segment diminishes by two from a base of six, then $\psi_t = 0.26$. Alternatively, suppose the more important segment diminished by two while the other diminished by only one. Then, $\psi_t = 0.34$. This simply illustrates the effect of weighting and the possibility for simultaneous consideration of parallel marketing channel segments.

Properties

An index based on pricing points is an obviously naive and crude measure since it is sensitive only to changes occurring in total integration among stages, given a base time. A preferable property for an index would be sensitivity to changes in the degree of integration between stages.

The usefulness of the index is limited to temporal measurement of integration. It should not be used for cross-sectional comparisons. Also, since the index is based solely on changes in number of vertical pricing points, it is appropriate only for approximating change in integration relative to a base time. The index cannot detect absolute levels of integration existing within a channel at a particular point in time since it is a time-relative index.

Estimation

An obvious advantage of a pricing point index is its relative ease of estimation. The index could be readily and inexpensively estimated by Delphi techniques compared to other possible indices. Also, because of its simplicity and amenability to Delphi estimation, the index would be tractable for historical periods. This is in contradistinction to an index based on primary or secondary individual firm data which may be impossible to obtain for significant historical periods.

A Vector Index

Definition

A second vertical integration index could be based on the extent of integration which exists at each stage or level within a marketing

channel. A necessary assumption is that the marketing channel for which the index is computed exhibit the ordering restrictions for a vertical marketing system.[4/] Given this, an interindustry index may be defined as:

$$(3)\quad \theta = \Gamma'\Gamma/K$$

where $0 \leq \theta \leq 1$, $\bar{K}$ is the number of stages or levels in a particular marketing channel prior to the final consumption stage (i.e. k=1, ...,K), Γ represents a vector whose elements, λ_k, are the fraction of output at the k^{th} level that is transferred to plants of the same firm at a succeeding level, and where Γ' is Γ transpose. The elements of Γ would be defined as:

$$(4)\quad \lambda_k = \Sigma Y_i / \Sigma X_i, \qquad Y_i \leq X_i \text{ for each } i$$

where X_i is the amount (either dollar value or quantity) of product produced by the i^{th} firm at the k^{th} level and Y_i is the amount of product which is an intrafirm interindustry (or interplant) transfer.[5/] The elements of Γ thus represent the weighted ratio of intrafirm interindustry transfer to total output for each level within a marketing channel.

As an example of the index, suppose a marketing channel consists of three stages prior to the final consumption stage (K=3), where exactly one-half of all output ($\Sigma Y_i / \Sigma X_i = 0.5$) at each stage is integrated with firms at a succeeding stage. Thus, $\lambda_k = 0.5$ for each k, $\Gamma'\Gamma = 0.75$, and $\theta = 0.25$.

The limits of θ occur when $\lambda_k=0$ for all $k(\theta=0)$ and $\lambda_k=1$ for all $k(\theta=1)$. The index is essentially composed of the percent output which is integrated divided by the maximum value of $\Gamma'\Gamma$. The maximum value of $\Gamma'\Gamma$ may be shown to be K by:

$$(5) \quad \lim_{\lambda_k \to 1} \Gamma'\Gamma = \lim_{\lambda_k \to 1} \sum_{k=1}^{K} \lambda_k^2 = K$$

When an individual λ_k is formulated as the ratio of interplant transfer to total output as in equation (4) above, equal weight is attached to units of output with no consideration or weight given to the number of firms at a particular level (in an industry) within the marketing channel. For some applications, a different algorithm for λ_k which simultaneously reflects the amount of integration and inequality of market share among firms within an industry may be desirable. To reflect both, an individual λ_k could be formulated as:

$$(6) \quad \lambda_k = \sum_{i=1}^{N} (Y_i X_i^3)^{\frac{1}{2}} / (\Sigma X_i)^2$$

where Y_i and X_i are defined as in equation (4) and there are N firms at the k^{th} level.

With this formulation, if all N firms within an industry are completely integrated and have equal market share then $\lambda_k=1/N$. That is, if all N firms have equal market shares and are completely integrated then λ_k is simply the reciprocal of the number of firms in that industry. Also, if one firm becomes the industry (i.e. N=1) the expression reduces to $(Y/X)^{\frac{1}{2}}$, meaning that λ_k depends solely on the interplant transfer ratio for that one firm. The limit of λ_k is 1.0, as

before, but is reached if and only if there is but one firm at the k^{th} level and that firm is totally integrated.

It is not clear that a formulation for λ_k as in equation (6) would be superior to a formulation as in equation (4) in all applications. In actual application, simple correlation analysis between the formulation in equation (4) and some horizontal concentration measure (such as the Herfindahl index) may yield more insight into structure than sole use of the equation (6) formulation.

Properties

The index, θ, is similar in concept to the Herfindahl index, a well-known horizontal concentration measure (Grossack, Vernon). Two properties considered desirable for a horizontal concentration index are:

1. The index increases (decreases) with increasing (decreasing) inequality of market share among a given number of firms.
2. The index decreases (increases) with an increase (decrease) in the number of firms.

The vector index θ exhibits the analogous first property, but not the second. That is, θ increases (decreases) with an increasing (decreasing) amount of vertical integration between levels, for a given number of levels. The second analogous property would be that a vertical integration index decreases (increases) with an increase(decrease) in the number of levels. However, for a vertical integration index this analogous property would not be desirable. A preferrable property for a vertical integration index would be that the

index had the same value, given the same integration, regardless of the number of levels. Thus, a channel of K levels compared with a channel of K+C levels, where C is an arbitrary positive integer, would have the same index if λ_k were equal for all k. This is true of the measure θ. However, once a base of K levels was established for a particular marketing channel, all K levels would need to be included from that time forward in order to secure time comparable measurement.

Unlike the pricing point index, the vector index is sensitive to the degree of integration between levels in a marketing channel. Also, the vector index is suitable for both temporal and cross-sectional comparisons. Cross-sectional suitability arises since marketing channels of varying number of levels produce the same θ, given that between level integration is identical.

One additional substantial difference between the pricing point index and vector index is that the former is based solely on change in number of pricing points over time. This renders it incapable of measuring the "absolute level" of integration at a particular point in time. The vector index, however, is sensitive to both absolute and time relative integration, once a base of K levels for a marketing channel has been established.

Estimation

Appreciation for quantification of either an individual λ_k or θ may be obtained by examining primary limitations of other proposed measures of integration. A general indictment of a majority of vertical integration measurement techniques based on conventional data sources is

that vertical integration tends to be defined by the measurement technique. This is in contrast to first defining vertical integration and then designing an acceptable measurement technique. Some elaboration of this and other difficulties become more apparent by reference to specific measurement techniques.

There are at least three alternative ratios which could be utilized as estimators of λ_k besides the interplant transfer approach suggested above. These ratios include: (1) income to sales, (2) inventory to sales, and (3) value added to sales. All three ratios have similar limitations. Since in each the denominator reflects sales, the magnitude of the ratio is confounded with the level (k) for which the ratio is computed. For example, suppose K=3, then suppose value added is exactly one dollar at each level with the value of output at the primary level at one dollar. Then, the value added to sales ratio is 1.0 for k=1, 0.67 for k=2, and 0.33 for k=3. Yet, each level may be "equally" integrated (Adelman, p. 282). Obviously, the ratio reflects the level within the marketing channel rather than the degree of integration. Other limitations specific to each ratio will not be reviewed here (see Adelman and Barnes for elaboration).

The interplant transfer approach is not without limitation. Income, inventory, value added, and sales are conventionally collected data, while interplant transfer is available for only a limited number of products for a limited number of levels within a marketing channel. Quantification using interplant transfer as the estimation method for λ_k would, in most instances, require primary data collection. Also, if interplant transfers are measured in dollar units then different firms

may value the same transfer differently. This limitation could be mitigated however by calculation of the interplant transfer ratio in physical units.

Application

Interest in vertical integration from a policy perspective is primarily attributable to its potential influence on market performance. No index or other measurement device by itself will explain either the extent of vertical integration or its relationship to market performance. However, requisite to quantitatively testing hypotheses concerning vertical integration is design of an acceptable quantitative vertical integration measure. An acceptable index can provide a means of empirically testing hypotheses, in a structural equations context, concerning both what causal factors explain observed degrees of integration and what impact integration has on market performance.

Of course, measurement difficulty is the perpetual Nemesis of hypothesis verification. An acceptable index would facilitate testing leading hypotheses concerning impetus for integration, such as risk aversion, economies of size, technology adoption, and/or high market transaction costs (for others see Arrow and Williamson). A major barrier to empirically testing such hypotheses now is lack of appropriate secondary data for various agricultural marketing channels. Design of an acceptable index represents the initial step toward identification of data for quantification of vertical integration.

Summary and Conclusions

Two algorithms have been suggested for an interindustry vertical integration index. The first algorithm involves integration measurement based on change in number of pricing points over time. Although admittedly a crude measure, the advantage of this long term temporal measure is the simplicity with which it could be estimated. The Delphi technique would serve as a relatively inexpensive means for estimation of a pricing point index. However, such an index is not of sufficient sophistication to play a role in most structural analyses.

The second algorithm measures interindustry vertical integration based upon aggregation of vertical integration at each level. The index is basically a vector whose elements are estimates of the degree of vertical integration at each of K levels in a marketing channel. Individual elements of the vector can be formulated in different ways, depending on whether or not inequality of market shares is to be considered simultaneously with the degree of vertical integration. Also, individual elements can be estimated by several alternative ratios which serve as estimates of vertical integration at a particular level (intraindustry vertical integration). The index is appropriate for both temporal and cross-sectional comparisons of vertical integration.

Footnotes

1. Some writers have referred to industry and market as being conceptually identical. In this manuscript, differentiation between industry and market is useful. As Olson states "Marketing and industries are not the same and it promotes clarity to distinguish between them and the performance of each. The transaction is the key difference between market and industry, ... Moreover, two or more industries are involved in transactions except in consumer markets and intro-industry transactions such as those for hedging, arbitrage, and balancing supplies among firms" (Olson, p.10). Also for purposes of this manuscript, horizontally arrayed markets (i.e. geographically disparate submarkets for the same commodity) are considered as a pricing point within a marketing channel.
2. Other studies have measured vertical integration and/or diversification for firms at a particular level in a marketing channel by using Standard Industrial Classification (SIC) code definitions of levels. Gort designed a measure of intraindustry vertical integration based on the ratio of employment in all "auxiliary activities" to aggregate employment for the firm (Gort).

A study of diversification and merger of grain firms utilized a diversification index defined from the number of SIC industries in which a firm was engaged (Cobia and Farris).

Some other divergent vertical integration measurement techniques have been designed reflecting various levels of aggregation. Laffer utilized the ratio of sales to gross corporate product by broad industry classifications (Laffer). Another approach by Rogers was to weight the rows and columns of a conceptual matrix on integration (owner, contract and cooperative) which defined an index (Rogers). Bucklin provides a second interesting conceptualization of market channel flows which has implication for vertical integration measurement (Bucklin).

3. Only in the limiting case where $P_{t+1} = 1$ will $\psi_t = \infty$. If $P_{t+1} > 1$ then $\psi_t < 1$. For practical purposes, when $P_{t+1} = 1$ then ψ_t may be regarded as 1.0 or complete integration. Also, a case of vertical disintegration (where $P_t < P_{t+1}$) would not produce a meaningful index, however this is not considered a severe limitation since examples where pricing points have increased over time within an agricultural commodity marketing channel are difficult to conceive.

4. Ordering restrictions on a vertical marketing system simply imply that stages or levels within the channel are sufficiently well-defined so as to allow ordering the K levels. For example, at an arbitrarily chosen k^{th} level, the product sold at that level is as near to its final completion in all dimensions and nearer on some than at the k-1 level (Richartz, pp. 185-188).

5. The Y variable could be defined differently for types of vertical integration other than ownership. For example, Y could be the amount of product which is either an interplant transfer or the amount of output under interindustry contract. Thus, Y could reflect either or both ownership and contractual integration. However, if Y were used as a proxy for both contractual and ownership integration, temporal and cross-sectional interpretation difficulties would arise from mixing varying degrees of entrepreneurial control gained or lost through integration into the same measure. From this standpoint, Y is perhaps best conceived as either an estimate of ownership or contractual integration.

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