A General Concentration Index for Multiproduct Firms with Differentiated Products

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ABSTRACT. Economists commonly use the Herfindahl-Hirschman Index (*HHI*) to measure the competitiveness of markets. However, the *HHI* has two significant problems. First, defining the market boundaries can be arbitrary. Second, the products included in the defined market are effectively assumed to be homogeneous. This paper proposes a differentiated product concentration index (*DPCI*) that reduces these problems by weighing substitutes differentially. The *DPCI* mitigates the problematic effects of expanding a market definition to change the perceived degree of competition. The *DPCI* has many desirable properties and collapses to the *HHI* when products are homogeneous. (D43, L11, L40)

I. Introduction

The measurement of market power and the determination of relevant market boundaries have long been of concern to economists both in general research and for antitrust purposes. Various concentration indices, including the Herfindahl-Hirschman Index (*HHI*), have been used indicate the degree of competition in markets and the degree of firms' pricing power. Yet the *HHI* presents a significant problem. Using it effectively assumes that all the products included in the defined market are homogeneous. A related issue in using a concentration index like the *HHI* lies in defining the market to measure. The choice of placing a boundary around the appropriate market can be challenging and arbitrary. This paper proposes a new concentration index, the differentiated product concentration index, a more flexible index than the *HHI* when firms compete within related, but not perfectly substitutable, markets.

As an illustration, consider the market for carbonated soft drinks. Within this market there are bottled soft drinks, canned soft drinks, and soft drink syrups sold in bulk. These consist of, for example, colas and non-colas, and sugared soft drinks and diet soft drinks. There are other

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substitutes as well: non-carbonated fruit drinks, iced-tea drinks, energy drinks and, perhaps more distantly, water. Which of these potentially substitutable beverages should be included in a concentration index with soft drinks?

Perhaps the relevant market should be more narrowly defined than all soft drinks. Bottled diet lemon-lime carbonated drinks may be sufficiently different from sugared cola syrups that they should be in separate markets. On the other hand, suppose the market is indeed defined as carbonated soft drinks and only carbonated soft drinks. The *HHI* then ignores the constraining power that fruit juice, water, iced-tea drinks, and energy drinks have on the prices of soft drinks. The market could instead be widely aggregated so that these latter substitutes are included. However, using the *HHI* then implicitly assigns the more distant substitutes the same price constraining power as the close substitutes of soft drinks.

At its heart, the choice of market boundaries for the *HHI* involves the notion of substitutability. If products are perfectly substitutable, they certainly should be included in the market definition for a concentration index. If products are perfectly not substitutable, they certainly should not be included in the concentration index. The issue of inclusion or exclusion of products in a concentration index arises not in the black and white cases of perfect substitutes or perfect non-substitutes, but in the gray areas of imperfect substitutes. As products are typically differentiated, most are imperfectly substitutable with one another, so the ambiguity of the gray areas frequently arises.

Depending on the chosen market boundaries, a number of different concentration index values could be calculated for a soft drink market. Still, the question remains as to which would best describe the market. Stigler (1982, p. 9) hints at the dilemma of defining markets by asserting that "the concentration ratios will be awesome or trivial," depending on who wins an argument to define a market. The *HHI* faces a puzzle in defining the relevant market and, therefore, in portraying the amount of competition in the market. A concentration index is needed that can effectively include all substitutes so that the choice of market boundaries is not such a critical issue.

Different products may have different capabilities to constrain the prices of its substitutes. Stigler and Sherwin (1985, p. 562), in tackling the problem of determining which products (or submarkets) ought to be placed together in the same (overall) market, noted that separate "[sub]markets can show every level of interdependence from absolute homogeneity to complete independence." It would be useful to have a

concentration index that provided a middle ground between the absolute homogeneity of products and their complete inclusion in an index (thereby weighing the products fully) and the complete independence of products and their complete exclusion from an index (thereby not weighing the products at all). This would allow the level of competition to be gauged more effectively.

A step in the direction of a new concentration index was undertaken by Lijesen (2004), who derived a Herfindahl-Hirschman type index with regard to product quality differences. The general finding was that higher quality products should be weighted more in a concentration index than lower quality products. Cesari (2000) used "transitional probabilities" to model customers switching between firms and suggested an index that multiplied customer loyalty by market share to form a "Fidelity Index" to measure the degree of non-competition in a market. Bailey and Taylor (2009) developed an index for differentiated single product firms. The present paper extends the Bailey and Taylor article.

We introduce an alternative to the *HHI,* the differentiated product concentration index (*DPCI*). The *DPCI* can be useful in much the same settings as the *HHI* has been useful, but the *DPCI* allows for differentiated accounting of differentiated products while alleviating problems associated with defining market boundaries.

Interest in alternate measures to the classical Herfindahl-Hirschman Index can be found in numerous recent economic papers across economic subfields. Recent papers in financial economics such as Wen-Yu (2013), Amidu-Wolfe (2013), and Berger, et. al. (2009) use alternate *HHI* measures based on deposits and loans in analyzing competition between banks. In energy economics, Hellmer and Werell (2009) uses an alternate *HHI* measure, developed by Melnik, et al. (2008) based on the two largest firms market shares, to examine market power in the Nordic electricity markets. In agricultural economics, Qin and Zhang (2012) use an alternate *HHI* measure to calculate degree of income specialization. They use multiple categorizations of related income categories to derive multiple *HHI* measures. Examples of the need for alternate *HHI* measures are certainly not limited to these few areas. In section VI, we present examples of potential usage of our alternate measure in the areas of industrial organization, trade, and sports economics.

II. Differentiated Product Concentration Index

Consider the *HHI* with the market divided into *N* submarkets and multiple firms dividing the submarkets, where a submarket is a grouping of products that have a very high degree of substitutability between each other relative to their substitutability to products outside the submarket. The *HHI* value for firm-f can be expressed in the unusual form given by

$$C_f^{HHI} = \left[\sum_{n=1}^{N} \sigma_n s_{nf}\right](\sigma_1 s_{1f}) + \left[\sum_{n=1}^{N} \sigma_n s_{nf}\right](\sigma_2 s_{2f}) + \ldots + \left[\sum_{n=1}^{N} \sigma_n s_{nf}\right](\sigma_N s_{Nf}) \quad (1)$$

In equation 1, the fraction that a submarket has of the overall market is called a "submarket share" and is denoted by σ_n for submarket-*n*. The fraction that a given firm's products have of the relevant submarket is a "firm share" or "product share" and is denoted by s_{nf} for firm-*f*'s products in submarket-*n*. Thus, $\sigma_n s_{nf}$ is the market share that firm-*f*'s products in submarket-*n* have as a fraction of the overall market. Firm *f*'s total market share is then

$$S_f = \sigma_1 s_{1f} + \sigma_2 s_{2f} + \ldots + \sigma_N s_{Nf}.$$

The index number, C_f^{HHI}, is then firm *f*'s total market share squared. (This paper takes market shares σ and s to have the range 0 to 1, not 0 to 100, as is sometimes done.)

With *F* firms in a market, the *HHI* value for the overall market is,

$$HHI = \sum_{f=1}^{F} C_f^{HHI} = \sum_{f=1}^{F}\left[\sum_{m=1}^{N}\left[(\sigma_m s_{mf}) \cdot \sum_{n=1}^{N}(\sigma_n s_{nf})\right]\right] \quad (2)$$

As shall be seen below, the *DPCI* value for the overall market will be

$$DPCI = \sum_{f=1}^{F}\left[\sum_{m=1}^{N}\left[(\sigma_m s_{mf})\cdot\sum_{n=1}^{N}\frac{\sigma_n s_{nf} b_{mn}}{B_m}\right]\right] \quad (3)$$

The differences between the *HHI* and *DPCI* lie in the presence of the terms b_{mn} and B_m. These terms represent respectively, the substitutability of products between submarkets *m* and *n*, and the fraction of the overall market in which submarket *m* products effectively compete. The *HHI* takes the substitutability between all products in the defined market to be 1 (perfect) and the fraction of the market in which all products effectively compete as 1 (the entire market). However, as differentiated products are not perfectly substitutable, they do not compete with the same effectiveness against the entire market. Note, however, if all products in the market are, in fact, perfectly substitutable, then $b_{mn} = B_m = 1$ for all *m* and *n*, and the *DPCI* collapses to the *HHI*. This is indicated in Property 1 below.

A user of the *DPCI* has some flexibility in how to compute the substitutable parameter b_{mn} depending on the context. For example, in an anti-trust or industrial organization context, the substitution parameter could be taken as a function of the cross-price elasticity between the goods in two related markets. Alternatively, per the Department of Justice merger guidelines for the Hypothetical Monopolist Test, the percentage of sales lost to products in each competing market is a measure of substitutability. Other potential methods of computing substitutability parameters are considered in Section VI.

Using the *DPCI*, a firm may have multiple products in a submarket, but a given product is considered to be in only one submarket.[1] The *DPCI* is flexible with regard to the fineness of submarket division; a submarket may be a single product.[2] An overall "market" is the grouping of submarkets that have non-negligible substitutability with the core, or target, submarket(s).

The substitutability of submarkets is given by the parameters b_{mn}, which have a range from 0 (no substitutability) to 1 (perfect substitutability). The subscripts *m* and *n* each count the submarkets up to the total of *N* submarkets. A substitutability parameter for which $m \neq n$ is a "between submarket" substitutability parameter. It designates the substitutability between submarket-*m* products and submarket-*n* products. The parameter b_{12} indicates the relative degree to which ostensible buyers of submarket-2 products would consider buying products from submarket-1, and b_{21} indicates the relative degree to which ostensible

buyers of submarket-1 products would consider buying products from submarket-2.[3] Put another way, b_{mn} indicates how far products in submarket m can reach into submarket n.[4] A substitutability parameter for which $m = n$ is a "within submarket" substitutability parameter, b_{mm}. All products in a given submarket are deemed to have the same substitutability.[5]

These substitutability parameters are (1) used to scale the results when a firm's total market share is multiplied together (as in an *HHI*-type calculation) and (2) to determine effective market sizes. In the terms of Cesari (2000), the substitutability parameters are related to the probabilities of customers moving from a given submarket in period-1 to another submarket in period-2 in a two period model.

Regarding point (1), the substitutability parameters serve to differentiate submarkets (and products). The larger a parameter value, the less differentiated the submarkets, and the more that a multiplication of market share leads to a *HHI*-like result. The smaller the substitutability parameter value, the more differentiated the submarkets, making the result less like the familiar *HHI* outcome.

Regarding point (2), the *DPCI* uses the concept of "effective market size," as denoted by B_m, to show the size of the market in which a product in submarket-m effectively competes. The effective market size incorporates the notion that a product in submarket-m may compete intensely with other products in its own submarket and only to a lesser degree with products in other submarkets. This effective market size is the effective share of the overall market that ostensible buyers in a given submarket actually choose from. If all products in the overall market are equally substitutable ($b_{mn} = b$ for all m and n), the effective market size is 1 for each product. If products in submarket-m are essentially not substitutable with other products in the overall market, and submarket-m is very small, the effective market size for products in submarket-m is near 0.

ally, the effective market size is defined as $B_m = \sum_{n=1}^{N} \sigma_n b_{mn}$. In determining B_m, each submarket share (σ_n) is multiplied by the substitutability of submarket-m with submarket-n (b_{mn}); the resulting sum is the effective market size for products in submarket-m. Larger substitutability parameter values cause the effective market size to rise. If market segments are more substitutable, products effectively compete in a larger fraction of the overall market. The effective market size can be viewed as a weighted average substitutability of all market products for those products in submarket-m.

The market share that a firm's product has of its effective market is

$(\sigma_n s_{nf})/(B_m)$. Whenever substitutability is unequal for some products (i.e., if $b_{mn} \neq b$ for some m and n), the effective market size, B_m, will be less than 1. The presence of the B_m parameters tends to inflate market shares, which by itself would indicate greater market power. Because a product might not truly compete in the entire market, but only a portion of it, its true market power in its effective market may be greater than its nominal market power as indicated by its nominal overall market share. Ceteris paribus, the smaller the effective market size that a product competes in, the greater the market power for its producer within its (smaller) effective market, or niche.

Consider now the *DPCI* value for an arbitrary firm. Given N submarkets, for firm-f this is,

$$C_f^{DPCI} = \sum_{m=1}^{N}\left[(\sigma_m s_{mf}) \cdot \sum_{n=1}^{N} \frac{\sigma_n s_{nf} b_{mn}}{B_m}\right] \tag{4}$$

With F firms in a market, the concentration index value for the overall market is $DPCI = \sum_{f=1}^{F} C_f^{DPCI}$. This can be written as,

$$DPCI = \sum_{f=1}^{F} C_f^{DPCI} = \sum_{f=1}^{F}\left[\sum_{m=1}^{N}\left[(\sigma_m s_{mf}) \cdot \sum_{n=1}^{N} \frac{\sigma_n s_{nf} b_{mn}}{B_m}\right]\right] \tag{5}$$

The index can be constructed and thought of as follows. First, find each product's market share, which is $\sigma_n s_{nf}$. Second, inflate this market share by dividing it by the effective market size in which the product competes, to reflect the product's market power in its effective market. This is $(\sigma_n s_{nf})/(B_m)$. Third, for the firm, multiply each of its effective market shares by each of the firm's (actual) market shares, $\sigma_m s_{mf}$, and by the substitutability parameter, b_{mn}, linking the submarkets m and n. Then sum the market share multiplications. This generates the firm's concentration index value. Total the index values for all firms to find the market concentration index value.

The *DPCI* value for a firm consists of the submarket shares of the firm multiplied by an increasing function of the submarket shares of the firm. That is, for a firm, each $(\sigma_m s_{mf})$ is multiplied by each $(\sigma_n s_{nf} b_{mn})/(B_m)$. As is usual for a concentration index, a larger index value for the *DPCI* denotes a more concentrated market, implying a less competitive market.

III. Market Delineation and Distant Substitutes

Although the *DPCI* can include all non-negligible substitutes for the targeted submarket products, market boundary issues may still arise with its use. But a strength of the *DPCI* is that the omission of distant substitutes has less marginal impact on the *DPCI* value than similar omissions have on *HHI* values. Thus, the *DPCI* is less sensitive to market boundary definitions than is the *HHI*. This is illustrated in examples 1 and 2 below.

A. EXAMPLE 1

Consider a case of three related submarkets, X, Y, and Z. Let each submarket be of equal size and be inhabited by a single (different) firm. Suppose submarkets X and Y are moderately substitutable, with between submarket substitutability values of $b_{XY} = b_{YX} = .5$. Also suppose submarket Z is only distantly substitutable with either X or Y, with between submarket substitutability values of $b_{XZ} = b_{ZX} = .1$, and $b_{YZ} = b_{ZY} = .2$. (Within submarket substitutability values are $b_{XX} = b_{YY} = b_{ZZ} = 1$.) If just submarkets X and Y are considered to comprise the overall market, the *HHI* value is .5. But if all three submarkets are considered to be the relevant market, the *HHI* value is .333. The analogous *DPCI* index values are .667 for just submarkets X and Y, and .660 for all three submarkets. For the *HHI*, the inclusion or exclusion of submarket Z is important in determining the index value, while for the *DPCI*, the inclusion or exclusion of the distantly substitutable submarket Z makes little difference.

B. EXAMPLE 2

Consider four related submarkets, A, B, C, and D, where each submarket is of equal size and each is inhabited by two equal-sized (and unique) firms. Let submarkets A and B contain near substitutes, with $b_{AB} = b_{BA} = .8$. Next, let submarket C contain moderate substitutes for A and B, with $b_{AC} = b_{CA} = .5$ and $b_{BC} = b_{CB} = .7$. Finally, let submarket D contain more distant substitutes, with $b_{AD} = b_{DA} = .2$, $b_{BD} = b_{DB} = .3$, $b_{CD} = b_{DC} = .4$. (And with $b_{AA} = b_{BB} = b_{CC} = b_{DD} = 1$.) The *HHI* values are for a market of just submarkets A and B, .25; for submarkets A, B, and C combined, .167; and for all four submarkets, .125. The analogous *DPCI* values are for just submarkets A and B, .278; for submarkets A, B, and C combined, .215; and for all four submarkets, .209. Again, the inclusion or exclusion

of the moderate substitutes in submarket C and the more distant substitutes in submarket D have more dramatic impacts on the *HHI* values than on the *DPCI* values.

As the *HHI* treats distant substitutes in the same way that it treats very close substitutes, the marginal decreases in index values as the market definition expands tend to be greater for the *HHI* than for the *DPCI*. Halting the progressive expansion of the defined market at any point tends to be less critical in defining the level of competition for the *DPCI* than for the *HHI*.

IV. *DPCI* Properties Shared with the *HHI*

Below are properties the *DPCI* shares with the *HHI*. Due to space constraints, formal proofs of all properties are available at http://sites.google.com/site/raisanenecon/home/research. Properties 1-3 demonstrate that the *DPCI* is defined on the same zero to one range as *HHI* and that the two are identical measures if the products in the submarkets are perfectly substitutable.

Property 1: If all products are equally substitutable, a firm's concentration index value is the square of its overall market share, and the *DPCI* is equivalent to the *HHI*.
Property 2: The maximum value for the *DPCI* is 1.
Property 3: The infimum value for the *DPCI* is 0.

V. Product Concentration Index Properties of the DPCI

Encaoua and Jacquemin (1980) list a number of desirable properties for a homogeneous product concentration index. For the homogeneous case, the *DPCI* shares the properties of the *HHI*. For the differentiated product case, three of the Encaoua and Jacquemin properties are extended here for the *DPCI*. The first is that a transfer of share from a smaller market share to a larger market share should increase concentration. This is presented in section V.A. The second is that a merger of market shares should increase concentration. This is presented in section V.B. The third is that a greater number of equal sized market shares should lower concentration. This is presented in section V.C. Together these properties show the *DPCI* has the desirable properties of a product concentration index.

A. MARKET SHARE TRANSFER

Properties 4 and 5 indicate that a transfer of share from a smaller market share firm to a larger market share firm increases market concentration as measured by the *DPCI*. This is true both within a given submarket and for changing concentrations between submarkets.

> Property 4: When product share is transferred within the same submarket, from a firm with a smaller product share to a firm with a larger product share, the market concentration index value rises, given equal product shares in other submarkets.[6]
> Property 5: Assume constant between submarket substitutability, constant within submarket substitutability, submarkets of equal size, and equal firms shares within submarkets. Then the market concentration index value falls whenever there is an increase in the number of firms in a more concentrated submarket along with a simultaneous decrease in the number of firms in a less concentrated submarket, such that the submarket concentration rankings do not reverse.

B. MERGERS

Mergers increase concentration by reducing the number of firms operating in a market and increasing a firm's market share. Properties 6 and 7 show that mergers within a submarket and mergers of firms in different submarkets both increase *DPCI*. Property 8 shows the effect of merging two submarkets into one.

> Property 6: When two firms in the same submarkets merge, the market concentration index value rises.
> Property 7: If there is substitutability between their submarkets, when two firms without a common submarket merge, the *DPCI* value rises.

Together Properties 6 and 7 imply that if two firms merge that have at least one common submarket or if there is some substitutability between their pre-merger submarkets, the market *DPCI* value rises following the merger.

> Property 8: Given constant between submarket substitutability, merging two submarkets into one is equivalent to raising the between

submarket substitutability parameter values linking the two submarkets to the level of the within submarket substitutability parameter values for the two submarkets.

C. NUMBER OF FIRMS OR SUBMARKETS

A greater number of equal sized firms lowers concentration. Properties 9-11 show that increasing the number of identical firms decreases *DPCI* in the cases of firms that operate in different submarkets, firms that operate in all submarkets, and firms that operate in overlapping submarkets.

Property 9: Given a submarket containing just single submarket firms, when the number of equal-sized firms in the submarket rises, the submarket and market concentration index values fall.
Property 10: Given firms of equal size operating in all submarkets with identical submarket shares, when the number of firms rises, the *DPCI* falls.
Property 11: Given submarkets of equal size, equal submarket substitutability, and constant within market substitutability, if some firms are not in all markets, as the number of submarkets rises, the *DPCI* falls.

VI. Implementing the DPCI

A key step in using the *DPCI* is to estimate suitable substitutability parameter values. If the substitutability parameters are thought to be like probabilities as in Cesari (2000), surveys could be used to track consumers' probability of switching between sellers and products. Huettner (2002) remarks that the characteristics which make products closer substitutes include product prices more closely tracking each other and a cross price elasticity nearer unity. Hence, real price (or quantity) correlations or cross price/own price elasticity ratios are suitable candidates for substitutability parameters. In other contexts, different substitutability measures could be uses.

A. DPCI IN INDUSTRIAL ORGANIZATION

There are clear applications of the *DPCI* within industrial organization.

As early as Hausman, Leonard, and Zona (1992), shortcomings of the Herfindahl-Hirschman Index as applied to anti-trust policy for firms competing with differentiated products were identified. Firms often compete in multiple markets in related industries. Apple Inc., for instance, produces desktop and laptop computers, tablets, smart phones, digital music players, and competes in digital content markets. A concentration index that views Apple within just a single market will produce a distorted view of the company. Using cross-price elasticity data to construct the submarket substitutability parameters as the ratio of cross-price to own-price elasticities, results in a much more complete view of Apple as a company and the competition they face rather than just within a given market.

As applied to anti-trust policy, the *DPCI* is less sensitive to market definitions than is the *HHI* and can be easier to analyse in the context of horizontal merger guidelines. Section 4 of the 2010 Department of Justice and Federal Trade Commission Horizontal Merger Guidelines, outlines the Hypothetic Monopoly Test for determining a market's definition.

The Agencies employ the hypothetical monopolist test to evaluate whether groups of products in candidate markets are sufficiently broad to constitute relevant antitrust markets. The Agencies use the hypothetical monopolist test to identify a set of products that are reasonably interchangeable with a product sold by one of the merging firms.

Once the *HHI* is applied the products included in the market definition are deemed perfectly interchangeable. Use of the *DPCI* avoids this complication and is less likely to overstate the competitiveness of a given grouping of markets.

B. DPCI IN INTERNATIONAL TRADE

One method of examining the impact of trade liberalization on markets is to examine the effect on the *HHI* of opening up international markets for a given industry. The result of local firms facing an increase in international competition can be seen in the decline in industry *HHI*s as the market definition changes from within-state to an international region. A firm that was a local monopoly can be placed into a competitive market by lowering trade barriers. This approach can be seen in the Hernandez and Torero (2013) paper examining local and regional market

concentration *HHI*s on pricing behaviour. Treating local and foreign markets as perfectly substitutable, as the *HHI* does in this context, overstates the impact that trade liberalization is likely to have. Our *DPCI* measure allows for a more measured approach to estimating the impact of trade liberalization.

Consider the case of two countries with market sizes of 0.75 and 0.25 respectively, each with a monopoly firm in a given industry. Before liberalization, each country has an *HHI* and *DPCI* of 1. Combining the markets initially yields two firms with market shares 0.75 and 0.25 respectively and thus a market *HHI* of 0.625. If we recognize the two markets as not perfectly substitutable, perhaps due to a consumer preference for local goods, a substitutability parameter can be estimated. Actual post-liberalization trade flows provide strong guidance on what the substitutability parameter should be. Taking $b_{mn}=0.5$ for $m \neq n$ in this case yields a post-liberalization *DPCI* of 0.743. The substitutability parameter can track the degree of competition provided. The *DPCI* takes this into account whereas the *HHI* cannot.

C. DPCI IN SPORTS ECONOMICS

In sports economics, *HHI* is used to estimate competitive balance between teams in a league. Teams do not always play schedules of equal difficulty, but the *HHI* treats all games as equal. Owen, et al. (2005) and Humphreys (2002) examine the benefits and drawbacks of using the *HHI* measure in this context. Our *DPCI* measure provides a clean method for adjusting the competitive balance measure. The traditional competitive balance measure uses the square of wins by a team over games played in the league as the team concentration index and the sum of these team-win concentrations as the *HHI* with higher values denoting less competitive balance. In larger leagues teams play an unbalanced schedule, playing fewer teams outside their division/conference and the rest of their games against teams within their division/conference. By examining how each conference fairs against each other conference, the substitutability parameter of inter-conference games can be computed and used in calculating the *DPCI*. If all divisions are equally skilled, the inter-conference records are 0.500, and the substitutability parameter can be taken as unity yielding equivalence between the *HHI* and *DPCI* measures. As conferences differ, inter-conference games should be treated as less of a substitute than intra-conference games. In this case,

the substitutability parameters decline and the *DPCI* increases as the league becomes less competitive, whereas the *HHI* would stay constant.

VII. Conclusions

This paper has proposed and examined a new concentration index, with the objective of introducing a more comprehensive and flexible alternative to the *HHI*. Products in the defined market are no longer considered equally substitutable with each other, as they are when using the *HHI*. The *DPCI* instead allows the degree of substitutability between products to vary. Thus, for products differentiated by characteristics or geography, the *DPCI* has a better ability to account for a differentiated ability to constrain market power than the traditional *HHI*.

Further, by using the *DPCI* rather than the *HHI*, researchers do not face the same burden in determining market boundaries. In principle, all non-negligible substitute products are included in the defined market when using the *DPCI*, which can solve the market boundary problem. Yet the problem of market boundaries may still remain, in practice. Crucially, however, the delineation of market boundaries tends to be less critical in determining concentration index values when the *DPCI* is used rather than the *HHI*. Thus, much of the market definition problem associated with the *HHI* is avoided.

As demonstrated in section V, the *DPCI* has the properties that economists like for a concentration index. In particular, the index possesses the two important characteristics that Encaoua and Jacquemin (1980) give that concentration indices should exhibit in homogeneous (equally substitutable) markets. First, the transfer of market share from a smaller firm to a larger firm should not decrease the concentration index value. Second, when firms merge, the concentration index value should not decrease. The first characteristic is given in Property 4; the second characteristic is given in Property 6. Finally, for homogeneous products, the *DPCI* has the same properties as the *HHI*.

The *DPCI* is essentially an expansion of the *HHI*. Therefore, many of the problems and strengths associated with the *HHI* are also associated with the *DPCI*. For example, a concentration index does not precisely measure market power, whether in antitrust use or general research use. It is instead a useful tool in indicating market power. Hence, one can always construct a case in which a market more completely dominated by

a single firm is more competitive than a less concentrated market. The *DPCI* appears no more likely than the *HHI* to fall afoul of such hazards, however.

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Endnotes

1. Identical products could be sold by different final sellers, who may inhabit different submarkets, as determined by the relevant substitutabilities. Products would then be differentiated by locations or sellers' characteristics, rather than by direct product characteristics. For example, differentiation by seller characteristic was argued in the aborted Staples-Office Depot merger, see Dalkir and Warren-Boulton (1999). With this modification, a final seller's product sold at a given location is in only one submarket.
2. A mathematical standard could be set for defining a separate submarket. This could be a minimum substitutability that all products in the submarket must have for all other products in the submarket. The notion of a submarket can be essentially eliminated by letting every product be a monopoly product in its own submarket.
3. It can be expected that b_{mn} and b_{nm} generally rise and fall together.
4. Substitutability can vary depending on prices. A substitutability parameter value may then be with respect to some given price, for example, the competitive price or the actual price.
5. Internally, each submarket is treated as an *HHI* market is, all products are equally substitutable.
6. Property 4 causes the within submarket concentration index value to be minimized when the product shares in the submarket are equal.