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FORMALIZING PRODUCT COST DISTORTION:

The Impact of Volume-Related Allocation Bases on Cost Information

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The purpose of this study is to formally analyze product cost distortions resulting from the process of allocating costs to products based on Activity-Based Costing (ABC) and the conventional product costing systems. The model developed in this paper rigorously shows the impact of treating costs that are not volume related as if they are. The model demonstrates that the source of product cost distortion is the difference between the proportion of driver used by each product in ABC and the proportion of the base used by the same product in the conventional costing systems. The difference arises because the conventional costing systems ignore the existence of batch-related and product-related costs.

The model predicts a positive association between volume and size diversity with product cost distortions. When interaction between volume and size diversity exists, the distortion is either mitigated or exacerbated. The magnitude of the distortion is jointly determined by the size of the differences and the size of the total indirect costs.

Keywords: activity-based costing; indirect costs; product cost distortions; size and volume diversity

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Introduction

Over the last ten years, management accounting literature has shown a growing interest in alternative approaches to conventional product costing systems. Conventional costing systems were developed in a period when technology was stable, the range of products was limited, and direct labor and direct materials were the predominant factors of production.

With dramatic changes in the environment in which organizations operate —such as global competition, technological advances, and access to low-cost information systems— a successful organization must take every advantage it can to remain competitive. Accurate cost information is one source of competitive advantage. Conventional costing systems have been criticized for providing misleading information about a company's competitive opportunities. Under these systems, information is produced too late, too distorted, and too aggregated to be relevant for management decision making (e.g. Malmi 1999; Brimson 1991; Johnson and Kaplan 1987). The Activity-Based Costing (ABC) system improves the accuracy of product costing by more accurately tracing the cost of the activities to products.

Conventional costing systems assume that there is a proportional relationship between volume and cost. Thus, each time a unit of the product is manufactured it is assumed that costs are incurred. This assumption justifies the use of volume-related bases such as direct labor hours, machine hours, or material dollars to allocate indirect costs to products. The proportion of indirect cost allocated to each product depends on the proportion of direct costs consumed by the product. Thus, if product A consumes ten times more direct labor hours than product B, then ten times more indirect cost will be allocated to product A than to product B (assuming that direct labor is used as the allocation base). This assumption only makes partial sense. Direct costs (direct materials, direct labors, and other direct costs), do vary in proportion to the volume of production. However, this assumption does not hold for most indirect costs. Most of the indirect costs are volume unrelated. For example, when products are manufactured in batches, high-volume products are often manufactured in larger batch sizes therefore requiring fewer engineering set ups, orders, and material handling per unit than low-volume products.[1]

ABC, on the other hand, assumes that activities cause costs, and that cost objects create the demand for activities. Researchers have argued that because of increasing product diversity and production process complexity, most activities are not volume-related. Thus, allocating the costs of such activities using volume-based allocation (as employed by the conventional costing system) results in cross-subsidization among different products.

The purpose of this paper is to develop and manipulate an algebraic model of the product cost distortion resulting from the process of allocating costs to products based on *ABC* and the conventional costing system. The source of product cost distortions previously identified in *ABC* literature will be formalized and evaluated using an approach of identify-

[1] The high-volume products are manufactured in batches of large volume, whereas the low-volume products are manufactured in small batches. For example, if the ratio of production volume in each batch between product A and product B is 10:1, then product A is called high-volume whereas product B is called low-volume.

ing product cost distortions first introduced by Gupta (1993).[2] Numerical simulations are used to illustrate the impact of using the volume-related base in allocating indirect costs to products.

This study contributes to the existing *ABC* literature by formally analyzing the source of product cost distortion through a direct comparison between the *ABC* costing model and the conventional costing model. In doing so, the model rigorously shows the impact of treating costs that are not volume related as if they are. Consistent with the intuition of Cooper (1988) and Cooper and Kaplan (1987), the model demonstrates that the source of product cost distortion is the difference between the proportion of driver used by each product in *ABC* and the proportion of the base used by the same product in the conventional costing system. The difference arises because the conventional costing system ignores the existence of batch-related and product-related costs.

By assuming that the proportion of driver used by each product is consistent across activity drivers such that the relation between the proportion of driver used by any two products is preserved across activity drivers, the model predicts: first, a positive association between volume diversity and the product cost distortion, in which the high-volume products are over-costed and the low-volume products are under-costed; second, a positive association between size diversity and the product cost distortion, in which the large size products are over-costed whereas the small size products are under-costed.[3] When interaction between volume diversity and size diversity exists, its effect on the product cost distortion could either mitigate or exacerbate the distortion. The association between volume-size diversity and the product cost distortion is stronger when a company produces both high-volume, large size products and low-volume, small size products (the interaction is exacerbated). On the other hand, the association between volume-size diversity and the product cost distortion is weaker when a company produces both high-volume, small size products and low-volume, large size products (the interaction is mitigated).

The remainder of this paper is organized as follows: In section two, a review of existing literature in *ABC* is presented, followed by the product costing models in section three. Section four analyzes the product cost distortions and generates some propositions and hypotheses, followed by numerical examples and discussions about the product cost distortions. Finally conclusions and directions for future research are presented in section five.

Review of the Literature

ABC has been extensively discussed in management accounting and cost accounting literature for the last decade. The need for more accurate product costs challenges the conventional view of product costing, which was designed to serve ex-

[2] Gupta (1993) developed a model of identifying product cost distortion due to aggregation in the cost allocation system. By comparison, the product cost distortion discussed in this paper is not the result of aggregation process per se. The model developed in this paper takes into account that the allocation bases in ABC, in general, are not a subset of the allocation bases in the traditional costing systems.

[3] The size diversity is defined as the difference in the resource consumption pattern between large products and small products. Even though the large size products consume significantly large amounts of volume-related input (i.e. direct costs), these products consume relatively same amounts of the volume-unrelated input (i.e. overhead costs).

ternal financial reporting purposes. For external reporting, it does not matter if there are cross-subsidies among products, as long as the total value recorded for inventory is sufficiently accurate. Therefore, it is not surprising that *ABC* originated not from accounting but from production and marketing specialists in companies that were seeking better ways to manage indirect costs. The activity-based concepts introduced by academicians such as Gordon Shillinglaw and George Staubus in the early 1960s did not influence academic thinking until recently.[4]

This has changed dramatically since the introduction of the *ABC* concept during 1980s. The chief incentive driving the development of *ABC* was the search for better product cost information to guide product mix, customer mix, and pricing decisions. Managers often distrust information produced by conventional costing systems in making product related decisions. One important distinction between *ABC* and the conventional costing systems is that *ABC* recognizes that not all costs vary in proportion to production volume. *ABC* classifies cost behavior into four types: unit related, batch related, product related, and facility related.

Cooper (1990) argued that the four cost behavior categories model contemporary production processes. The four levels of activities (called hierarchy) that create costs are unit, batch, product, and facility related activities.

Under *ABC*, costs are assigned to products more accurately based on the activities that create costs. *ABC* recognizes that some costs vary in proportion to batches, products, or facility and are allocated accordingly. Some advantages of *ABC* over conventional costing systems have been discussed in the literature and include enhanced product cost accuracy[5] (Lewis 1993; Cooper 1988; Cooper and Kaplan 1987), more relevant information for managerial decision making (Cotton et al. 2003; Gupta and King 1997; Turney 1992), and providing information about value-added activities (Armitage 1992; Brimson 1991).

While considerable anecdotal evidence has been reported in the literature regarding the impact of *ABC* in providing more accurate product costs, there are relatively few analytical studies on product cost distortions. Existing *ABC* literature has focused primarily on methodological (Ostrenga 1990; Cooper 1989; 1988) or operationalization issues in *ABC* implementation (Drumheller Jr. 1993; Bhimani and Pigott 1992; Shank and Govindarajan 1988). One possible explanation is that the distortion can only be measured if we know the true cost numbers. Unfortunately, it is questionable whether we ever know the true numbers (Gupta 1993).

Hwang et al. (1993) develop a framework to analyze a company's expected economic loss from product cost distortion. They formally analyze the magnitude of product cost distortions that result from using a single allocation base. They show (analytically) that the product cost distortion is a function of a) the degree of heterogeneity of the production technologies;[6] b) the relative magnitude of per unit input costs; and c) the product mix. They concluded that management must care-

[4] For a good review of the activity based costing history, see Johnson (1992).

[5] The focus of this paper is limited to the ability of the ABC system to improve product cost accuracy.

[6] Heterogeneity of production technology is defined as the difference in production process complexity among products.

fully analyze the nature of the company's economic environment in selecting allocation bases for indirect costs.

Gupta (1993) develops a product costing model to analyze the source of product cost distortions. The model is designed to analyze the aggregate impact of product cost allocation on product costing. It provides an insight into the source of product cost distortions and will be used as the starting point for the product costing models developed in this paper.

By comparison, the models presented in this paper recognize that product cost distortions of *ABC* as compared to the conventional costing system are not due to aggregation per se, but result from totally different assumptions and allocation bases. For instance, the *ABC* system recognizes that there are different level of activities in the company such as unit activity, batch activity, and product activity. Different activity levels require different types of activity drivers. The activity drivers could be the number of customer orders, the number of engineering setups, the number of movements, the number of shipments, or the number of material handling hours. In contrast, the conventional costing systems recognize only unit activity and usually use direct labor hours as the allocation base.

The Model

The Ideal Costing System

Causality is the central concept in product costing particularly with respect to providing information for managerial purposes. Shillinglaw (1989) argues that any assignment of cost that does not reflect causality is irrelevant for managerial use and is potentially dangerous.

The ideal costing system uses causality in assigning costs to products. This system assumes that activities cause costs and that cost objects create the demand to perform certain activities. Theoretically, it is possible to trace and record the amount of each individual cost consumed by each product at each activity. This ideal costing system can be described as follows.[7]

Consider a company that produces *P* products, denoted by *p* (p=1...P), that are produced using *A* distinct activities denoted by a (a=1...A). The total cost allocated to product *p* using direct costs (direct materials, direct labor, and other direct costs) and indirect costs can be formally stated as (for comparison purposes, the direct costs are separated from the indirect costs).

Equation 1:

$$TCI_p = \sum_{x=1}^{X} \frac{TDC_x}{TUD_x} TUD_{xp} + \sum_{a=1}^{A} \frac{TIC_a}{TUB_a} (TUB_{ap}) \quad \forall p = 1 \ldots p$$

Where:

TCI_p : total costs allocated to product *p* using ideal costing system;

TDC_x : total direct cost type *x* (x=1...X);

TUD_x : total units of direct cost type *x* used;

TUD_{xp} : total units of direct cost type *x* used by product *p;*

TIC_a : total indirect costs in activity *a;*

TUB_a : total units of driver in activity *a;*

TUB_{ap} : total units of driver in activity *a* used by product *p*.

[7] It is assumed that this ideal costing system will generate the true product costs.

This ideal costing system incorporates all activities concerning the use of total product costs (TC). Since this ideal costing system requires the measurement of every input consumed by every activity and every activity consumed by every product, this system would be prohibitively expensive. It is impractical to trace all possible activities that cause costs because ultimately each of the company's individual support resources might be viewed as being consumed by distinct activities. Cooper (1989) argued that one of the considerations used to decide how many activity drivers to be used is the relative costs of the activity traced. That is, the cost of tracing the activities must not exceed its benefit. It is also impossible to trace every input consumed by every activity. In practice, a firm must compromise at some point by including multiple activities in one activity driver. Consequently, some degree of product cost distortion is unavoidable (Hwang et al. 1993; Brimson 1991).

Activity-Based Costing (ABC)

ABC is as a method of measuring the cost and performance of activities, resources, and cost objects; assigns resources to activities and activities to cost objects based on their use; and recognizes the causal relationship of activity drivers to activities.[8] It should be noted that although *ABC* uses causality in tracing costs, for practical reasons, some activities are not cost effective to be traced. The assumption underlying this definition is that activities cause costs and that cost objects create the demand for activities (Lewis 1993; Turney 1992). The causal relationship between the activities and costs is called activity drivers. Activity drivers serve as bases to allocate costs to the cost objects to reflect the causality relationship.

As mentioned earlier, the ideal costing system is impractical because it is not cost effective to trace all possible activities that cause costs. For convenience, similar activities are combined and treated as one activity with a single activity driver which is selected as an allocation base. Thus, *ABC* is not a perfect system. Some degree of structural distortion still exists due to aggregation processes in selecting activities.

In designing *ABC*, most companies use an operational analysis approach in which people from different areas of the company get involved in the process of determining the causal relationship between cost objects, activities, and resources that are consumed (Armitage 1992; Bhimani and Pigott 1992). This approach is used to develop a comprehensive understanding of the process and activities of the business and how they relate to one another.

For the purpose of this paper, *ABC* will serve as a benchmark against which the conventional costing system will be evaluated. By assuming that the true product cost is generated from the full causality model (i.e. the ideal costing system described in "The Ideal Costing System" section, *ABC* would be considered as a proxy for the ideal costing model since *ABC* also uses causality in tracing costs (partial causality as opposed to full causality). The ideal costing system is not used as

[8] This definition was developed by Computer Aided Manufacturing International (CAM-I), a consortium of organizations that engage in joint research into new management techniques.

a benchmark because it is practically unobservable. *ABC* might be seen as an internal benchmark[9] to establish baseline product costs against which the conventional costing system will be compared. This benchmark, in turn, could be used to compare the company product costs with those of external competitors. *ABC* starts by grouping homogeneous actions into activities and then further aggregates them into activity centres or processes (Cooper 1989). *ABC* requires cost pools for each defined activity. Costs are attached to only those products that use the activity. Direct costs (direct materials, direct labors, and other direct costs) are charged directly to products. Indirect costs which cannot be traced to each unit of product costs are allocated on the basis of activity drivers which reflect the variability of the activity.

Based on a study of fifty cost systems in thirty one companies, Cooper (1990) concludes that the cost function of the innovative companies can be adequately described as a linear formula that is the sum of unit level costs, batch level costs, product level costs, and facility level costs.[10]

Consider a company which produces *P* products denoted by *p* (p=1...P) that are produced using direct costs (direct materials, direct labors, and other direct costs) and indirect costs caused by *D* (1≤D≤A) distinct activities denoted by *d* (d=1...D).

The direct costs are unit-level costs (that is, they vary in proportion to production volume,) while the indirect costs could fall into unit, batch, product or facility costs and thus will be allocated based on the type of activities that capture the underlying behavior of the costs. Product costing under *ABC* can be stated formally as follows:

Equation 2:

$$TCA_p = \sum_{x=1}^{X} \frac{TDC_x}{TUD_x} TUD_{xp} + \sum_{d=1}^{D} \frac{TIC_d}{TUB_d} (TUB_{dp}) \quad \forall p = 1...p$$

Where,

TCA_p : total costs allocated to product *p* using *ABC*;

TDC_x : total direct cost type *x* (x=1...X);

TUD_x : total units of direct cost type *x* used;

TUD_{xp} : total units of direct cost type *x* used by product *p*;

TIC_d : total indirect costs in activity *d*;

TUB_d : total units of driver in activity *d*;

TUB_{dp} : total units of driver in activity *d* used by product *p* .

Again, for comparison purposes, the direct costs are separated from the indirect costs, although, in practice, all costs are assigned to products through activity drivers (i.e. for the direct costs, the drivers are direct materials, direct labors, and other direct activity drivers).

The total cost of product *p* (p=1...P) is equal to the sum of the proportion of direct costs and indirect costs used by the product in activity *d* (d=1...D).

Conventional Costing Systems

Conventional costing systems assume that products create costs in proportion to volume. Costs are classified as either di-

[9] The Society of Management Accountants of Canada (1993) defines internal benchmarks as a comparison of an organization's own similar processes, products, or services (p. 9). Comparing ABC to the conventional costing system might be viewed as a comparison between two processes of allocating costs to products.

[10] In ABC literature, these types of costs are sometimes refer to as the activity hierarchy.

rect (direct materials, direct labors, and other direct costs) or indirect. Direct costs are defined as costs that can be identified specifically with a specific cost object in an economically feasible manner. Indirect costs are defined as costs that cannot be identified specifically with a single cost objective in an economically feasible manner (Horngren et al. 2000). Direct costs are charged directly to products. On the other hand, indirect costs are allocated to products using volume-related allocation bases such as direct labor hours, machine hours, or material costs (e.g., Hardy and Hubbard 1992; Brimson 1991).

Most firms use a single allocation basis to charge indirect costs to products. Horngren et al. (2000), based on survey data, reported that a vast majority of manufacturers (over 80%) use a single allocation basis (either direct labor hours or direct labor dollars).[11] The indirect costs are allocated using a two-stage procedure. In the first stage, indirect costs are pooled in cost centres. In the second stage, the cost accumulated at the cost centres are allocated to products using volume-related allocation bases such as direct labor hours, machine hours, or direct material dollar (Boons et al. 1992; Cooper 1990). Horngren et al. (2000) assert that the choice of the allocation base should be guided by a) the purpose to be served by the cost allocation, and b) the necessary clerical costs and effort in allocation. They argue that the volume-related bases are commonly used because information on the number of direct costs associated with each product is readily available in many organizations.

Consider a firm which produces *P* products using direct costs (direct materials, direct labors, and other direct costs) and indirect costs. The direct costs are directly assigned to products while the indirect costs are allocated to products using a single allocation basis.

Assume that a company produces *P* products denoted by *p* (p=1..P) using direct costs and indirect costs. The product costing under this system can be stated formally as follows:

Equation 3:

$$TCC_p = \sum_{x=1}^{x} \frac{TDC_x}{TUD_x} TUD_{xp} + \frac{TIC}{AB} AB_p \qquad \forall p = 1...p$$

Where (other variables are as defined in Equation 2),

TCC_p : total costs allocated to product *p* using the conventional costing system;

AB : single allocation basis (could be direct labor hours, direct labor dollars, or machine hours),

AB_p : total units of allocation bases used by product *p*.

The total cost of product *p* (p=1...P) is equal to the proportion of direct costs and indirect costs used by the product.

Formalizing Product Cost Distortions

The product cost distortion is defined in this paper as the difference between cost allocated to products using *ABC* and the cost allocated to products using a costing system under consideration. Two types of product cost distortions will be discussed

[11] In a study of fifty cost system in thirty one companies, Cooper (1990) found that most systems used only one second stage allocation base to assign the expenses accumulated in a cost center to the products. The most common second-stage allocation base was direct labor.

in relation to *ABC*: the structural product cost distortion and the distortion resulting from the comparison between *ABC* and the conventional costing system. As mentioned earlier, *ABC* uses causality in tracing costs. Consequently, this system provides a better estimate of true costs as compared to the conventional costing system which uses only volume-related allocation bases.

Equation 4

$$\text{Dist.}_p\,(S) = \left\{\sum_{x=1}^{X}\frac{TDC_x}{TUD_x}TUD_{xp} + \sum_{a=1}^{A}\frac{TIC_a}{TUB_a}TUB_{ap}\right\} - \left\{\sum_{x=1}^{X}\frac{TDC_x}{TUD_x}TUD_{xp} + \sum_{d=1}^{D}\frac{TIC_d}{TUB_d}TUB_{dp}\right\}$$

$$\forall p = 1 \ldots p$$

The Structural Cost Distortions

The difference between the ideal product costing (Equation 1) and *ABC* (Equation 2) can be called a structural product cost distortion. Formally, this distortion can be shown as follows:

Assuming that the direct input costs (i.e. direct materials, direct labors, and other direct costs) are similar regardless of the costing systems[12] (this assumption will be used throughout this paper)(e.g., Lewis 1993; Hwang et al. 1993), Equation 4 can be simplified as follows:

Equation 5

$$\text{Dist.}_p\,(S) = \sum_{x=1}^{X}\frac{TIC_a}{TUB_a}TUB_{ap} - \sum_{d=1}^{D}\frac{TIC_d}{TUB_d}TUB_{dp}$$

$$\forall p = 1 \ldots p$$

By assumption, the product cost distortions are exclusively the result of the allocation of indirect costs to products. Notice that the total activity drivers in *ABC*, *D*, are smaller than or equal to the total activity drivers in the ideal system, *A*, ($1 \leq D \leq A$). Thus, each activity driver in *ABC*, denoted by d, consists of some activity drivers of the ideal system, denoted by a. Consequently, the total indirect costs of each activity driver in *ABC* are the aggregate costs of the multiple activity drivers in the ideal system ($TOC_d = \sum_{a \in d;\, a=1}^{A} TOC_a$). Gupta (1993) demonstrates that the distortion is equal to zero if the proportional resource used by a unit of product *p* at the aggregate level is the same as the proportional resource used in the disaggregate activity drivers. That is, the group activity driver is proportional to each component activity driver. Therefore, a strategy to reduce the number of activity drivers is to combine drivers that are the same or very similar into a single activity driver. Notice that the allocation bases used in each component activity driver are a subset of the group activity driver. The structural product cost distortions are simply the result of disproportional driver usage between a

[12] This assumption can be justified by the fact that the direct input costs can be traced economically to individual products. Thus, for the direct input costs, the number of activities in ABC is equal the number of activities in the "ideal" costing system.

certain group of activity drivers and its components which are a subset of the group activity driver. Thus, the distortions are exclusively caused by the aggregation process.[13]

The structural product cost distortion is not widely discussed in *ABC* literature. One potential explanation why this distortion is often ignored in the literature is that resolving the differences is not cost efficient, in the sense that the cost of resolving the differences would exceed its benefit. The rest of this chapter will be devoted to evaluating the sources of product cost distortions resulting from *ABC* as compared to the conventional costing system.

ABC and the Conventional Costing System Contrasted

Unlike the structural product cost distortion which arises due to the aggregation processes discussed in previous section, the product cost distortions, resulting from comparing product costing based on *ABC* and that of the single based allocation system, should take into account the differences in allocation bases used by the two different systems. In general, the allocation bases of *ABC* (which are called activity drivers) are very different from that of the conventional costing systems. The allocation bases of the conventional costing systems are usually direct labor hours, machine hours, or direct labor dollars which are, inevitably, also used in *ABC*. In addition to the conventional allocation bases, the activity drivers could be the number of customer orders, the number of engineering setups, the number of movements, the number of shipments, the number of material handling hours, etc., which in general are not the same as those of the conventional costing systems. However, the unit-related drivers used in *ABC* are usually the same as the allocation bases in the conventional costing systems.

By assuming that there are no distortions in allocating the direct costs (direct material, direct labor and other direct costs), the product cost distortions arising from the comparison between *ABC* and the single allocation base can be shown, algebraically, as follows:[14]

Equation 6

$$\text{Dist}_p(A) = \sum_{d=1}^{D} \frac{\text{TIC}_d}{\text{TUB}_d}\,\text{TUB}_{dp} - \frac{\text{TIC}}{\text{AB}}\,\text{AB}_p$$

$$\forall p = 1 \ldots p$$

Thus, the product cost distortion for a certain product *p* (p=1...P) is equal to the difference between the total indirect costs allocated to the product using activity drivers (ABC) and the total indirect costs allocated to the same product using a single allocation base (the conventional costing system).

It has been shown in the *ABC* literature that due to production complexity and product diversity, product costs in today's environment are generally not directly related to the production volume. Product costs, especially indirect costs, are propor-

[13] The distortion due to aggregation will not be discussed in detail in this paper. Readers interested in this issue should consult Gupta's paper "Heterogeneity issues in aggregated costing system," *Journal of Management Accounting Research* (fall, 1993): 180-212.

[14] This assumption is justifiable given that the direct materials and direct labor costs are volume-related costs and both *ABC* and the single-based allocating systems use the same "drivers" to assign these costs.

tional to unit, batch, product, and facility. Therefore, product costing systems that allocate indirect costs using only unit-related bases would produce inaccurate product costs. There will be a cross-subsidization among different products due to disproportional resources used in batch-related and product-related activities as compared to unit related activities.

As discussed in "Activity-Based Costing" section, *ABC* recognizes that costs vary in proportion to batch, production, facility, and unit activities. Consequently, the product cost distortions arising from comparing *ABC* and the conventional costing system are the differences in proportional usage of activities between the batch-related and/or product-related costs and the unit-related costs. Notice that if all products are manufactured in the same batch and/or if all products need the same product-related activities, then there will be no cross-subsidization among products (that is, there is no product cost distortion). In summary, the source of product cost distortions is the difference in driver usage in *ABC* and base usage in the conventional costing system resulting from diversity in batch-related and/or product-related activities among products.[15]

Volume Diversity

Volume diversity is defined as the difference in the resource consumption patterns between high-volume products (products that are manufactured in a large batch) and low-volume products (products that are produced in a small batch).[16] The high-volume products tend to consume significantly larger amounts of direct input costs as compared to the low-volume products. However, the proportion of overhead resources used per unit of the high-volume products is smaller than that of low-volume products. For example, to manufacture the same number of products, the high-volume products need fewer numbers of purchase orders, engineering setups, and product specification than those of the low-volume products. From this example, it is obvious that allocating overhead costs using volume-related bases tends to over-cost the high-volume products and under-cost the low-volume products.

Size Diversity

Size diversity is defined as the difference in the resource consumption patterns between large products and small products (Cooper 1989). Even though the large products consume significantly large amounts of volume-related input (i.e. direct costs), the large products consume relatively equal amounts of the volume-unrelated input (i.e. overhead costs).

Interaction between Volume and Size Diversity

The interaction between volume and size diversity could either mitigate or exacerbate the distortion. The interaction effect could be shown as a 2X2 matrix as follow.

Size		Volume: *High*	Volume: *Low*
Size	*Large*	1	2
Size	*Small*	3	4

[15] The facility-related costs are allocated using unit-, batch-, or product-related drivers.

[16] Cooper (1989) uses the terms volume diversity to describe the differences in batch sizes to manufacture products.

In cells 1 and 4, the product cost distortion is exacerbated, whereas in cells 2 and 3, the product cost distortion is mitigated.

To explore the source of product cost distortion due to the volume diversity and size diversity, Equation 6 can be rewritten in terms of the proportion of driver (ABC) and the proportion of the single allocation base (the conventional costing system) used by each product as follows:

Equation 7

$$\text{Dist}_p\,(\text{AS}) = \sum_{d=1}^{D} \frac{\text{TUB}_{dp}}{\text{TUB}_d}\,\text{TIC}_d - \frac{\text{AB}_p}{\text{AB}}\,\text{TIC}$$

$$\forall p = 1 \ldots p$$

Where $\frac{\text{TUB}_{dp}}{\text{TUB}_d}$ (total unit driver used by a certain product divided by total unit driver) is the proportion of driver *d* used by product *p* in the *ABC* system, and $\frac{\text{AB}_p}{\text{AB}}$ (total units of allocation basis, such as direct labor hours, used by product *p* divided by total unit of the allocation base) is the proportion of the total allocation base used by product *p* in the traditional cost system.

Since $\sum_{d=1}^{D} \text{TIC}_d = \text{TIC}$,[17] and $\frac{\text{AB}_p}{\text{AB}}$ is a constant for each *d*, Equation 7 can be rewritten as:

Equation 8

$$\text{Dist}_p\,(\text{AS}) = \sum_{d=1}^{D} \frac{\text{TUB}_{dp}}{\text{TUB}_d}\,\text{TIC}_d - \sum_{d=1}^{D} \frac{\text{AB}_p}{\text{AB}}\,\text{TIC}_d$$

$$= \sum \left\{ \frac{\text{TUB}_{dp}}{\text{TUB}_d} - \frac{\text{AB}_p}{\text{AB}} \right\} \text{TIC}_d$$

$$\forall p = 1 \ldots p$$

From Equation 8, it is sufficient to show that the distortion is equal to zero if $\frac{\text{TUB}_{dp}}{\text{TUB}_d} = \frac{\text{AB}_p}{\text{AB}}$, $\forall d = 1..D$ and $\forall p = 1..P$ (the proportion of resources use in each driver for product *p* (p=1...P) is equal to the proportion of resources used in the single allocation base for the same product). In other words, the product cost distortion is equal to zero if:

1) Only one product is produced (P=1). In this case, both the proportion of resources used in each driver $\frac{\text{TUB}_{dp}}{\text{TUB}_d}$ and the proportion of resources used in the single allocation base $\frac{\text{AB}_p}{\text{AB}}$ would be equal to one, and
2) All of these following criteria are satisfied:[18]

[17] This implies that the traditional costing system uses the full cost method in allocating overhead costs. Cooper (1989) argues that the full cost method is considered more appropriate for long-term decisions.

[18] By comparison, Gupta's aggregate product costing model does not require that all products use all drivers and that the driver usage be equal for all drivers in each product in order for the product distortion to be zero. As long as the proportions are the same within each "pool," the product cost distortion is equal to zero.

1. All products use all activities
2. The proportion of driver used in the *ABC* system must be equal to the proportion of the base used in the single allocation base for all activities and for all products.

Cooper (1988) intuitively asserts that: "*When the quantity of volume-related input that a product consumes does not vary in direct proportion to the quantity of volume-unrelated input consumed, volume-based cost systems will report distorted product costs*" *(p. 53).*

It is important to note that the difference between the driver usage and the base usage must be computed for all activities before summing up for each product. The product cost distortion can then be calculated by summing up all the differences between costs allocated to product p in each driver for all drivers used to produce P products.

It should be noted, however, that the criteria for zero product cost distortion described above is only a *sufficient* and *not a necessary* condition for the cost distortion to be zero, because of the cross-subsidization among drivers. Even if the proportional usage is not equal, the zero product cost distortion is still possible, because some activity drivers may be larger, while other drivers may be smaller than the proportional usage in the traditional costing system.

The criteria for zero cost distortion discussed above would become *necessary* and *sufficient* conditions by imposing into the model an assumption that the proportion of driver usage by each product has a consistent pattern such that

$\frac{TUB_{di}}{TUB_d} \geq \frac{TUB_{dj}}{TUB_d}$, $\forall d = 1 \ldots D$; where i and j represent two different products. Thus, the relation between the driver usage of the two products is preserved across drivers. Given these conditions, the source of product cost distortions can be explained as follows.

"Volume Diversity." When a company produces both high and low-volume products, $\frac{TUB_{dh}}{TUB_d} < \frac{AB_p}{AB}$, while $\frac{TUB_{dl}}{TUB_d} > \frac{AB_p}{AB}$ $d = 1 \ldots D$; where h and l represent the high-volume and the low-volume products respectively. That is, the proportion of resources used by the high-volume products is smaller than the proportion of the base used in the single allocation base. On the other hand, the proportion of resources used by the low-volume products is larger than the proportion of the base used in the single allocation base. This is because the conventional costing system treats overhead costs that are not unit related as if they are. This leads to the first proposition.

P_1: *There is a positive association between the volume diversity and the product cost distortion. The high-volume products tend to be over-costed whereas the low-volume products tend to be under-costed.*

"Size Diversity." When a company manufactures both small and large products, $\frac{TUB_{dl}}{TUB_d} < \frac{AB_p}{AB}$, while $\frac{TUB_{ds}}{TUB_d} > \frac{AB_p}{AB}$ $d = 1 \ldots D$; where l and s represent the large and the small products respectively. That is, the proportion of resources used by the large products is smaller than the proportion of resources used in the single allocation base. On the other hand, the proportion of resources used by the small products is larger than the proportion of resources used in the single allocation base.

Again, this is because the conventional costing system treats all costs as if they are unit related. This leads to the second proposition.

P_2: *There is a positive association between size diversity and the product cost distortions. The large products are over-costed whereas the small products are under-costed.*

"Interaction between Volume and Size Diversity." The interaction between volume diversity and size diversity exists whenever a company manufactures products of different sizes using different methods of production (high or low-volume). The small, high-volume products are doubly over-costed, whereas the large, low-volume products are doubly under-costed. In this case, the distortion is exacerbated. On the other hand, the product cost distortion resulting from the interaction between the small, high-volume product and the large, low volume product depends on the relative magnitude of the size diversity and the volume diversity of the product. In the 2X2 matrix presented before, in cells 1 and 4 the product cost distortion is exacerbated, whereas in cells 2 and 3 the product cost distortion is mitigated. This leads to the following propositions:

P_{3a}: *When the interaction is exacerbated, the association between volume-size diversity and the product cost distortion is stronger. The large, high-volume products are doubly over-costed and the small, low-volume products are doubly under-costed.*

P_{3b}: *When the interaction is mitigated, the association between volume-size diversity and the product cost distortion is weaker. The impact o n product cost distortion depends on the relative magnitude of the interaction between the volume diversity and the size diversity.*

These propositions lead to the third hypothesis,

"The Magnitude of the Distortion." Equation 8 suggests that the magnitude of the distortion is jointly determined by the size of the indirect costs (TIC) and the difference between the driver usage $\left(\frac{TUB_{dp}}{TUB_d}\right)$ and the base usage $\left(\frac{AB_p}{AB_d}\right)$

This leads to the following proposition.

P_4: *The larger the indirect costs and/or the larger the difference between the driver usage and the base usage, the larger the magnitude of the distortion.*

This proposition leads to the following hypothesis,

H_1: *Companies that have large amount of indirect costs are more willing to adopt ABC than companies that have small amount of indirect costs.*

Numerical Examples

As analytically shown in section 4.2, the source of product cost distortions is the difference in the proportion of resources used in each activity driver as compared to the allocation base used in the conventional costing system. This difference is caused by treating costs that are not unit related as if they are.

Following are numerical examples of how the difference in the driver usage (ABC) and allocation-base usage (the conventional costing system) influences the product cost distortion. Consider a company that produces products *A*, *B*, and *C*. For the purpose of discussions, assume that product *A* consumes three times the direct labor as products *B* and *C* respectively. Incidentally, the number of driver used by product *A* is also three times that of products *B* and *C* respectively. Table 1 shows conditions that result in zero product cost distortions.

Table 1. **Example of Zero Product Cost Distortion**

Panel A: Cost data

Product (p)	Dir. Labor Hours (AB_p)	No. of Setups (d=1)	No. of Orders (d=2)	No. of Handling (d=3)	Total Ind. Costs (TIC)
A	60	6	3	6	
B	20	2	1	2	
C	20	2	1	2	
Total	100	10	5	10	
Ind. Costs	-	$800	$400	$2,000	$3,200
	(AB)	(TUB_1)	(TUB_2)	(TUB_3)	

Panel B: Cost allocation

Description	Product A	Product B	Product C
ABC system (TUB_{dp}/TUB_d x TIC_d)			
(6/10 x 800) + (3/5 x 400) + (6/10 x 2000)	1,920		
(2/10 x 800) + (1/5 x 400) + (2/10 x 2000)		640	
(2/10 x 800) + (1/5 x 400) + (2/10 x 2000)			640
Single allocation base (AB_p/AB x TIC):			
60/100 x $3,200	1,920		
20/100 x $3,200		640	
20/100 x $3,200			640
Product cost distortion	0	0	0

Panel A shows the cost data of the company and panel B shows the product cost allocation under *ABC* and the conventional costing system. Thus, if the proportion of volume-related costs is equal to the proportion of non-volume-related costs, the product cost distortions are zero. This zero product cost distortion can also be calculated using Equation 8.

In practice, however, the proportion usually differs. The differences are due to volume diversity and size diversity as outlined earlier and have been widely discussed in management accounting literature. A more realistic example is presented in Table 2.

Table 2. **Example of Product Cost Distortions**
(Indirect costs do not vary in proportion to the volume related cost)

Panel A: Cost Data

Product (p)	Dir. Labor Hours (AB_p)	No. of Setups (d=1)	No. of Orders (d=2)	No. of Handling (d=3)	Total Ind. Costs (TIC)
A	80	2	1	3	
B	10	1	3	2	
C	10	5	1	3	
Total	100	8	5	8	
Ind. Costs	-	$800	$400	$2,000	$3,200
	(AB)	(TUB_1)	(TUB_2)	(TUB_3)	

Panel B: Cost allocation

Description	Product		
	A	**B**	**C**
ABC system (TUB_{dp}/TUB_d x TIC_d)			
(2/8 x 800) + (1/5 x 400) + (3/8 x 2000)	1,030		
(1/8 x 800) + (3/5 x 400) + (2/8 x 2000)		840	
(5/8 x 800) + (1/5 x 400) + (3/8 x 2000)			1,330
Single allocation base (AB_p/AB x TIC):			
80/100 x $3,200	2,560		
10/100 x $3,200		320	
10/100 x $3,200			320
Cost understatement (overstatement)	(1,530)	520	1,010

Consider a company that produces product *A* which is a high-volume (or large size) product, and product *B* and *C* which are low-volume (or small size) products. Panel *A* presents the cost data and panel B presents the product cost allocation under *ABC* and the conventional costing system. This illustration is used to show the source of product cost distortion resulting from the comparison of product costs based on *ABC* and the conventional costing system. For simplicity only three activity drivers are used by the company, even though in practice organizations that adopt *ABC* tend to use more activity drivers.

Table 2 shows that the high-volume (or large size) product is over-costed, while the low-volume (or small size) products are under-costed. The sources of the product cost distortions are the differences in the driver usage in *ABC* and the base usage in the conventional costing system. These differences arise because the conventional costing system ignores the batch-related and the product-related activities.

It is apparent that the sources of the distortion are the disproportional usage in the allocation bases between *ABC* and the conventional costing system. The magnitude of the distortion is jointly determined by the size of the difference and the size of the total indirect costs.

Discussions and Future Research

The sources of product cost distortion have been analytically discussed and numerical simulations have been presented to show the impact of treating costs that are not unit related as if they are. Empirical studies (e.g. Cooper and Kaplan 1987; Armitage 1992) have shown that overhead costs tend not to vary closely with units of products.

Contrary to prior beliefs, the existence of substantial overhead costs and the existence of many kinds of products are not the source of product cost distortion per se. As long as the resource consumed by each product is uniform across activities, the product cost distortion will not exist. This study shows that the source of product cost distortion is the difference in the driver usage in *ABC* and the base usage in the conventional costing system. The difference arises because the conventional costing system ignores the existence of batch-related and product-related activities. The magnitude of the distortion is jointly determined by the size of indirect costs and the difference between the driver usage (ABC) and the base usage (the conventional costing system).

ABC has the potential for a significant impact in improving product cost accuracy in companies that exhibit high volume diversity and/or high size diversity. Since high-volume and large size products consume significantly less number of activities as compared to the low-volume or small size products, the conventional costing system that use only volume-related allocation bases tends to over-cost the high-volume and/or large size products and under-costed the low-volume and/or small size products.

This inaccuracy in costing the products might result in misdirection when management uses this information for making decisions. This argument is consistent with the assertion made by Horngren et al. (2000) that the choice of cost allocation methods should be evaluated in terms of how the given alternatives influence management behaviour. Shillinglaw (1989) argues that the inaccuracy in product costing causes the failure of the costing system to help management in making product-related decisions. These ill-informed decisions become more important when companies compete in a market in which prices are not market driven (cost leadership market) or in markets where a multi-product company faces a focused competition. Substantial costing inaccuracies lead to unintentional strategy mistakes. For example, the high-volume and the large size products seem unprofitable under the conventional costing system and management might mistakenly stop producing these types of products and focus on the low-volume and/or small size products which seem profitable. In fact, the costing system's inaccuracy leads to the wrong decisions. In addition to more accurate product costs, given that *ABC* focuses its analyzes on activities, this system might potentially provides useful information to management in their effort to reduce costs.

Unfortunately, *ABC* is not yet widely applied in practice. Surveys conducted in different countries consistently report a low rate of *ABC* adoption (Cotton et al. 2003; Innes et al. 2000). Shillinglaw (1989) provides some reasons for the unwillingness of management to adopt this concept. '*First*, changes disrupt existing routines, add to costs, and increase uncertainty. Second, systems with multiple apportionment rates are more expensive than systems with fewer rates. *Second*, management has not been convinced that added accuracy would produce significant benefits.

This study can be extended in several directions. *First*, this study shows analytically that *ABC* provides more accurate information about product costs, particularly when volume and/or size diversity exist. It is interesting to study why despite the considerable anecdotal evidence that has been reported in the literature supporting the usefulness of *ABC* in providing more accurate information, *ABC* is not yet widely applied in practice. One possible reason of the low rate of *ABC* adoption is that managers might be committed to their existing product costing systems (i.e., the conventional costing systems) which make them insensitive to potential benefits of new initiatives such as *ABC*. Researchers (e.g., Jermias 2001; Argyris and Kaplan 1994) found that individual resistance to change is a major factor for not changing the traditional cost accounting system. A laboratory experiment might be used to study how prior commitment to the existing systems influence managers' evaluation of the usefulness of a new product costing system, and in turn their willingness to adopt the new initiative.

Second, notice that in the models several assumptions are imposed, such as the consistent behaviour of the driver usage across drivers, the zero product cost distortion from direct materials and direct labor costs, and the use of full costs in the traditional costing system. It is an empirical question whether these assumptions are valid in the real world.

Finally, the propositions generated in this study might be a useful guide in conducting a field study to evaluate how the *ABC* system, which recognizes the batch-level, product-level, and facility-level as well as the unit level activities, improves the accuracy of product costs.

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