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Analysis of UPS Proposals One and Two, and the Supporting Report of Dr. Kevin Neels

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I. INTRODUCTION

In Docket No. RM2016-2, United Parcel Service (UPS) has proposed three changes to the Commission approved product costing methodology.[1] As such UPS, has the burden of demonstrating that the proposed methodological changes will improve the accuracy of the product cost calculations. This could have occurred if UPS had provided a superior theoretical basis for calculating costs or an improved econometric analysis of existing Postal Service data. Neither of these possible improvements were incorporated in UPS's proposals.

Instead, UPS proposes two ill-advised cost allocation schemes that are inconsistent with established economic principles of cost measurement and acceptable econometric practice. These UPS proposals rely upon an expert report authored by Dr. Kevin Neels of the Brattle Group. The Postal Service asked me to review UPS Proposals One and Two, along with the expert report of Dr. Neels, to see if they provide potential improvements to the Commission-approved costing methodology and if they meet the burden associated with proposed methodological changes. My review revealed that they do not. As discussed below, the proposed methodological changes, along with the underlying analysis, suffer from a number of disqualifying defects. They include, *inter alia*:

- Misapplication of the cost concepts appropriate for a single-product firm to the Postal Service, which is a multiproduct firm.
- Mischaracterization of the nature of Postal Service costs.

[1] Only the first two proposed changes will be discussed in this report. The Commission deferred consideration of the third proposal until it makes a determination on the first two proposals. Order No. 2793 (October 29, 2015).

- Failure to actually implement a Shapley value analysis, and instead proposing a Fully Distributed Cost (FDC) analysis that produces results inconsistent with Shapley values.
- A substandard econometric exercise which includes inadequate model specification, insufficient data, and incomplete econometric methods. The purported results of the econometric analysis are spurious.
- Computational errors that compound the conceptual errors of the analysis.

II. COST CHARACTERISTICS OF THE POSTAL SERVICE

Calculating accurate product costs for the United States Postal Service is an important and challenging job. In the forty-five years since the Postal Reorganization Act, the Postal Service's product costing system has evolved, through the participatory regulatory environment, to meet the needs of a large, integrated, multiproduct firm.[2]

> The current cost system was developed over time with much thought and insight from well-known economists including William Baumol, John Panzar, and William Vickrey. It is worth noting that the Postal Service's cost procedures have been thoroughly reviewed over the years. In addition to numerous audits, the cost methodologies are reviewed annually by the PRC and have been debated during numerous public proceedings. In addition, a joint 1999 study by the Postal Service, the PRC, and the Government Accountability Office found Postal Service costing methods adequate for ratemaking purposes. (Footnotes omitted).

[2] See, Office of Inspector General, United States Postal Service, A Primer on Costing Issues, Report Number: RARC-WP-12-008, at 2.

Because of the unique economics of the Postal Service, standard single-product firm costing methods are inapplicable, and a more sophisticated cost measurement system is required. To understand and evaluate the Postal Service's product costing system requires a basic familiarity with the nature of cost generation in postal services. These characteristics were recently described in an Office of Inspector General Report:[3]

> The Postal Service is a multiproduct firm – This characteristic is important because average cost, the fundamental cost datum useful in single product industries, has no meaning in a multiproduct firm. For example, imagine a simple industry in which firms produce widgets and nothing else. In such an industry, annual unit widget costs can be easily calculated by dividing the total annual cost by the number of widgets. However, the Postal Service delivers several different types of product (e.g., delivered letters, parcels). Each of these products has different cost characteristics, so dividing total cost by number of total pieces of mail does not provide a meaningful number.
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> The Postal Service has many common costs – There are many activities in which several of the Postal Service's products are handled simultaneously. An excellent example is the time spent by a mail carrier on his delivery route. The carrier leaves the carrier office and passes by each address, all the time carrying different products (e.g., letters, flats, parcels). The cost of the carrier time expended in such an activity is both fixed with respect to volume and common to many products. Therefore, there is no justifiable economic algorithm for determining how much of such common costs should be assigned to an individual product.
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> The Postal Service is a network industry – In network industries there are cost advantages to handling products together, either more of the same product (economies of scale) or several different products (economies of scope). In the postal example, it may be cheaper on a per piece basis to deliver a letter and a package together than to have separate delivery routes for each type of mail product. As a

[3] Id.

> practical matter, the presence of such “economies” makes estimating the cost of products difficult, because costs vary as more (or less) of a specific product or service is provided.

These cost characteristics reveal that Postal Service has a relatively complex costing structure and its costs cannot be accurately measured through the use of simple single-product firm cost measures. To accurately measure postal product costs, the relevant cost measures must reflect the economics of a multiproduct firm.

III. THE ECONOMICS OF MULTIPRODUCT FIRMS

The fact that the Postal Service is a multiproduct firm is not a mere curiosity, but has important ramifications for the way that costs are generated and how they should be measured. For example, a number of the traditional single-product firm cost concepts are not applicable to a multiproduct firm:[4]

> The concept of average cost has no meaning in a multi-product firm like the Postal Service.

Erroneously applying single-product firm concepts to a multiproduct firm will lead to mis-measured costs and faulty inferences about those costs. The UPS proposals make this mistake and it severely undermines their accuracy and limits their applicability.

Before discussing the appropriate cost measure for multiproduct firms, it will be of value to define and discuss some basic costing terms. The concepts of fixed and variable costs are widely, and sometime erroneously, used in the UPS proposals. A fixed cost is one that remains even if the firms output falls to zero, like a mortgage payment on the firm’s building. As long as the firm is in existence, this cost is incurred,

[4] Id.

even if the firm is not producing any output. In contrast, a variable cost is one that increases with increases in the firms output, although the rate of increase may not be proportional. An example of a variable cost is the wage costs associated with the hours worked by production workers. These definitions are simple and straightforward to apply in a textbook context, but are more subtle and difficult to identify in real-world costing analyses. When computing costs for actual firms, it is not always clear which costs would remain if the firm ceased all production. Some costs may fall in a gray area. For example, by contract, the compensation rural carriers receive for the time spent driving their routes is not related to the volumes collected and delivered on those routes. This would seem to make this a fixed cost.

On the other hand, if the Postal Service had no volumes to collect or deliver, it is not clear that it would have its rural carriers drive their routes. This would seem to make this a variable cost. Fortunately, this distinction is not particularly important for most real-world costing exercises because most firms are not contemplating producing no output for all products. What is important is measuring how costs vary as the level of output of the firm's goods change. This is what the Postal Service's product costing system does and it is not of critical importance to identify whether a particular cost is "fixed" or "variable" in a textbook sense. The critical question is if, and by how much, a cost changes as the level of output changes, under current operations.

The difficulty in unambiguously determining whether a cost is fixed or variable in a textbook sense has led to the development of an intermediate type of cost, known as a "quasi-fixed" cost. Quasi-fixed costs are variable in the sense that their total amount will increase as the firm's output increases, but they will be unchanging over certain, potentially large, ranges of production. The key point is that real-world product costing rarely boils down to the simple identification of "fixed" and "variable" costs.

It may seem obvious how to define a multiproduct firm for economic analysis—it is simply a firm that produces more than one good or service. However, this simple definition is not sufficient, because it is possible for a firm producing more than one good or service to be just an aggregation of two or more single-product firms, with each unit within the firm not deviating from the economic structure of a single-product firm. Rather, the existence of a true multiproduct firm requires common production in which two or more outputs share at least one input in the production process. Importantly, the shared input(s) could be either fixed or variable in the classic sense; the key point is that the transformation of inputs into outputs is performed jointly across products. As a result, the economic structure of the multiproduct firm differs from the economic structure of a series of single-product firms, each making a single output.

This difference in economic structure implies a difference in the way costs are generated.[5] Consequently, there are different product cost measures in a multiproduct firm than there are in a single-product firm. First, multiproduct firms have common costs, which do not occur in single-product firms. Common costs are those costs that arise from the use of the common input in a multiproduct firm, and that input can be

[5] Formally speaking, the product transformation surface for a multiproduct firm is different from the series of individual product transformation surfaces for a series of single-product firms. This means that the multiproduct firm's production and cost functions are different from those of a single-product firm. See, Fuss, Melvin A., and Waverman, Leonard, "Regulation and the Multiproduct Firm: The Case of Telecommunications in Canada," in Studies in Public Regulation, Gary Fromm (ed.), The MIT Press, 1981 at 278.

variable or fixed. This means that common costs can be variable or fixed.[6] The key characteristic of common costs is that they are not individually caused by any of the firm's products and are not causally related to variations in the levels of those products' individual volumes. Thus, any method for allocating common costs to products is necessarily arbitrary and will lead to misleading cost measures:[7]

> Separating common costs by some measure of relative use is arbitrary and should not be used as a basis for price setting, since there is in general no connection between intensity of use and cost causation. Cost separation is a bogus issue that exists because of regulatory commissions' reliance on historical average costs as a guide to setting price. But there is no method of correctly separating historical average costs. Pricing rules based on efficiency criteria should be set at long-run incremental costs, thus avoiding any need to "separate" costs.

Second, multiproduct firms are characterized by the existence of the economies of scope.[8] Economies of a scope arise when it is cheaper for one firm to produce two or more goods simultaneously than it is for a series of single-product firms to produce the same goods. More formally, suppose that one partitions a firm's output vector, Q, into

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[6] These types of costs are sometimes called "joint" costs. The consensus, however, is that the term "joint costs" is reserved for the subset of common costs in which the outputs are produced in fixed proportions. Defined this way, joint costs are not generally applicable to the Postal Service.

[7] See, Fuss, Melvin A., and Waverman, Leonard, "Regulation and the Multiproduct Firm: The Case of Telecommunications in Canada," in Studies in Public Regulation, Gary Fromm (ed.), The MIT Press, 1981 at 284.

[8] Economies of scale occur in both single-product firms and multiproduct firms. For an explanation of economies of scale in a multiproduct firm, see Responses of The United States Postal Service to Questions 1-4 Of Chairman's Information Request No. 2, Docket No. RM2016-2, at Question 2.

individual products or groups of products, V_i.[9] Define the partition $P = \{V_1, V_2, \ldots V_k\}$ so that the union of the V_i is Q, the intersection of any two different V_i is the empty set, and each V_i is nonzero. Finally, let y_{V_i} measure the level of output for V_i. Then, there are economies of scope at y_Q with respect to the partition if:

$$\sum_{i=1}^{k} C(y_{V_i}) > C(y_Q).$$

In the case of two products, economies of scope imply that:

$$C(y_1, y_2) < C(y_1, 0) + C(0, y_2).$$

The existence of common costs and scope economies generates a third difference between the costs of multiproduct firms and the costs of single-product firms. In a single-product firm, the fact that a cost is variable implies that it can be included in the product's average cost and thus causally attributed to the product. No such condition holds in a multiproduct firm. The fact that a cost may be variable is not, in itself, a basis for attributing it to individual products, since commonality implies some costs, potentially including variable costs, are caused only by groups of products. A causal relationship between a cost and the individual product that generated it must be established for a reliable attribution to be made.[10]

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[9] The following analysis is taken from Baumol, William J., Panzar, John C., and Willig, Robert D., Contestable Markets and the Theory of Industry Structure, Harcourt Brace Jovanovich, 1987, at 71.

[10] This is not to say that an arbitrary, mechanistic allocation of common costs to products cannot be done.

To see this, consider the following simple multiproduct cost function. Suppose that the firm produces two products, has some common costs, and experiences economies of scope. The cost function could look like:

$$C(V_1, V_2) = \Theta + \gamma(V_1) + \delta(V_2) + \lambda(V_1 * V_2).$$

Where:

$$\Theta = \begin{cases} = 0 \ \ if\ V_1 = V_2 = 0. \\ > 0 \ \ if\ V_1\ and/or\ V_2 > 0. \end{cases}$$

$$\lambda = \begin{cases} = 0 \ \ if\ either\ V_1\ or\ V_2 = 0. \\ < 0 \ \ if\ V_1\ and\ V_2 > 0. \end{cases}$$

This cost function has no fixed costs as total costs go to zero if output falls to zero, yet not all costs are caused by, hence are attributable, to individual products.

A fourth difference between the costs in a multiproduct firm and a single-product firm is the fact that scalar quantities such as average variable cost, average fixed cost, and average total cost are meaningless in the multiproduct firm. Although they could be mechanically calculated, these average costs do not really exist because there is no way to construct a meaningful single measure of output to serve as the denominator:[11]

> The obvious stumbling block is that a multiproduct cost function possess no natural scalar quantity over which costs may be "averaged." That is, we cannot construct a measure of the magnitude of multiproduct output without committing the sin of adding apples and oranges.

[11] See, Baumol, William J., Panzar, John C., and Willig, Robert D., Contestable Markets and the Theory of Industry Structure, Harcourt Brace Jovanovich, 1987, at 47.

For example, one could take total the Postal Service's total volume variable cost in FY2014 of $39.2 billion and divided by the FY2014 total mail volume of 158.4 billion pieces to produce an "average" volume variable cost of $0.247 per piece. But that calculated number has no meaning, because it combines diverse products like High Density Letters that cost 6 cents apiece and First-Class Parcels that cost $2.40 each.

Fortunately, meaningful measures of cost do exist in a multiproduct firm. First, marginal cost, the change in total cost caused by provision of another unit of output, exists in the multiproduct firm:[12]

> As is well-known, when an enterprise produces more than one service under condition of joint or common costs (i.e., when there are economies of scope), there is no way to define the unit (average) cost of an individual service except through some arbitrary cost allocation procedure. The cost of a marginal unit of any service remains perfectly well-defined, however, since it merely involves the thought experiment of calculating the total costs of the enterprise with and without said unit and taking the difference.

The marginal cost for each product serves as the basis for setting a product's price, because it represents the resource cost to society of producing an additional unit of that output.[13] Thus, in order to not incur a financial loss by providing service, it should always be the case that a product's price at least equals its marginal cost. Use of marginal costs to set prices also provides a basis for economically efficient pricing:[14]

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[12] See, Direct Testimony of John C. Panzar on Behalf of the United States Postal Service, USPS-REM-T-2, Docket No. R90-1 (Remand) at 9.

[13] A product's marginal cost is the increase in total cost that occurs due to producing an additional unit of the product. This can be contrasted with a product's incremental cost, which is the increase in total cost from producing all of the product's units.

[14] See, Direct Testimony of William J. Baumol on Behalf of the United States Postal Service, USPS-REM-T-1, Docket No. R90-1 (Remand) at 6.

> The second main source of the importance of marginal cost is its role in economic efficiency. To see the relation, consider two firms, A and B, that together produce 1,000 widgets per day, of which A produces 575 and B produces the remaining 425. Would it be more efficient for A to produce a greater proportion of the 1,000-widget industry output, and for B to produce less of it, or would a move in the other direction be more economical? The answer is straightforward: if A's marginal cost of producing a widget is lower than B's it is more efficient for A to increase its output while that of B declines. The reverse will be true if B's marginal cost is the lower.

The other cost concept applicable to the multiproduct firm is incremental cost. The incremental cost of a product is the total cost caused by adding that product to the firm's output mix. Specifically, suppose that a firm produces N services. Then, the incremental cost of the i^{th} service is given by:[15]

$$IC_i(y) = C(y) - C(y_{N-i}).$$

Note that $C(y_{N-i})$ is the total cost to the firm of producing all of its goods before the ith good is added to its product vector. A product's incremental cost is the multiproduct firm analog to a product's total cost in a single-product firm. It is the total amount of cost caused by provision of all units of the product and can include both fixed and variable costs:[16]

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[15] See, Baumol, William J., Panzar, John C., and Willig, Robert D., Contestable Markets and the Theory of Industry Structure, Harcourt Brace Jovanovich, 1987, at 67.

[16] See, Panzar, John C., "The Role of Costs for Postal Regulation," manuscript, 2014 at 6.

> The economic concept of incremental costs is central to any notion of *cost causality*. To say that service (or group of services) *X causes* an expenditure *Y* is *equivalent* to saying that *Y* is the Incremental Cost of *X*.

Because a product's incremental cost is the total amount of cost caused by that product, assigning any additional cost to the product is misleading, distortionary, arbitrary and unnecessary. It is misleading because it produces a product cost measure that is different from the true amount of costs caused by the product. It is distortionary because it can lead to prices that will encourage inefficient entry and production. Society will not benefit from having the least cost producer provide the product. It is arbitrary because there is no causal basis for adding costs to incremental cost, so any such addition must rely upon arbitrary rules. It is unnecessary because a product's incremental cost already captures all of the cost caused by that product.

Just as incremental cost is the multiproduct firm analog of a product's total cost in a single-product firm, a product's average incremental cost is the analog of a product's average total cost in a single-product firm. The average incremental cost is just the product's incremental cost divided by the number of units produced, and when the firm has decreasing marginal costs for a product, its average incremental cost will be above its marginal cost.

Also, because a product's incremental cost is the total cost caused by the product, it is the appropriate basis for cross-subsidy testing. If a product's revenue exceeds its incremental cost, then it is not receiving a subsidy from other products in the firm. There is widespread agreement that incremental cost is the correct cost measurement in cross-subsidy testing:[17]

> This approach to the detection of cross-subsidy in regulated markets is by now standard in both economic theory and regulatory practice. I mention it here only to emphasize the fact that the role of incremental costs in the rate-making process occurs after rates are determined, to be used in detecting cross-subsidization.

Finally, incremental costs can be calculated for groups of products as well as individual products. The incremental costs for that group will never be smaller than and typically will be larger than the sum of the incremental costs for the products included in the group. A reason the incremental costs of the group will be larger is because it will include costs which are common to the group of products but not included in the individual incremental costs:[18]

> Although incremental costs clearly are based on cost causality, only the incremental costs of a single mail subclass can be unambiguously and nonarbitrarily identified with their source. When there are costs which would be avoided only when two or more subclasses of service are discontinued, any attribution of such costs amounts to an arbitrary partial cost allocation.

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[17] See, Direct Testimony of John C. Panzar on Behalf of the United States Postal Service, USPS-REM-T-2, Docket No. R90-1 (Remand) at 15.

[18] See, Direct Testimony of John C. Panzar on Behalf of the United States Postal Service, USPS-REM-T-2, Docket No. R90-1 (Remand) at 11.

IV. APPLYING MULTIPRODUCT FIRM CONCEPTS TO THE POSTAL SERVICE

Because the Postal Service is a multiproduct firm with both common costs and economies of scale (or density) and economies of scope, it is both appropriate and necessary to apply multiproduct cost concepts to the measurement of its product costs. To do otherwise would produce cost estimates that are erroneous and potentially misleading. The current product costing system applies multiproduct firm concepts and its methodology was jointly developed over a long period of time by the Postal Regulatory Commission, the Postal Service, and outside stakeholders including the Postal Service's customers and competitors.[19] The costing methodology is transparent, and has been publically vetted on numerous occasions and in numerous contexts.[20]

The PRC/USPS cost measurement of volume variable cost per piece, or unit volume variable cost, is an estimate of the relevant product's marginal cost.[21] That is, it estimates the change in total cost associated with a small, sustained increase or decrease in volume. To estimate unit volume variable costs, the PRC/Postal Service methodology usually first requires the estimation of total volume variable costs for all products as an intermediate step. Because of the complexity of Postal Service

[19] Previously under the PRA, as a practical matter, and currently under the PAEA, as a specific statutory directive, the Commission has been the final arbiter of the regulatory costing methodology followed by the Postal Service.

[20] See, Office of Inspector General, United States Postal Service, A Primer on Costing Issues, Report Number: RARC-WP-12-008, at 2.

[21] Formally, the PRC/USPS method adds product specific costs to volume variable costs. Because product specific costs are so small, this has virtually no impact on the measured marginal costs. As a matter of economic theory, product specific costs should be included in a product's incremental cost, not its marginal cost. Product specific costs can be fixed or variable.

operations, where different activities have distinct cost-generating processes, this computation is done at the cost component level. The PRC/Postal Service methodology estimates volume variable costs at the level of individual cost component and then sums them to obtain overall volume variable costs.

This micro-based approach also has the advantage of providing the data necessary to estimate the cost-generating relationships:[22]

> An important problem remains. Because of the joint provision of postal products, it is difficult and expensive to record data, at the level of the micro unit, on the volumes of mail by product. For example, it is very difficult and time consuming for the Postal Service regularly to identify how much mail of each class is loaded onto a tractor trailer ready for transport. To solve this problem, one must recognize the composite nature of the cost generating process in each activity. Within each activity, there is an action performed on the mail piece and that action generates cost. The action might be the transport of a letter on a truck or its delivery to an address. Cost is increased when the number of such actions is increased; when more addresses are receiving mail, delivery costs rise. The quantity of each of these actions is measured by what is known as a "cost driver." Cost drivers are best understood by example: in highway transportation, the cost driver is the number of cubic foot-miles required to transport the mail; in mail processing, the cost driver is the number of sortations of mail required to get each piece en route to its proper destination.

With this information, the total costs in any component, C_j, can be expressed as the sum of any fixed cost, F_j, and any variable cost, $\gamma_j(D_j)$.[23]

[22] See, Bradley, Michael D, Colvin, Jeff, Panzar, John C, "On Setting Prices and Testing Cross-Subsidy with Accounting Data," Journal of Regulatory Economics, Jul 1999, Vol. 16, No. 1, at 88.

$$C_j = F_j + \gamma_j\big(D_j\big).$$

Note that variable cost is determined by the amount of the cost driver, D_j, which is determined by the amount of volume, V_j.

$$D_j = \delta_j(V_i).$$

Total cost for the Postal Service is just the sum of the component costs:

$$C_j = \sum_j F_j + \gamma_j\big(\delta_j(V_i)\big).$$

A necessary step in estimating marginal cost is first finding the total volume variable cost each component, VVC_j. It can be found by multiplying the component's total cost by its cost elasticity or "variability."

$$VVC_j = \varepsilon_j C_{j.}$$

Where:

$$\varepsilon_j = \frac{\partial C_j}{\partial D_j}\frac{D_j}{C_j}.$$

This formulation permits decomposing a component's total cost into its volume variable portion, $\varepsilon_j C_j$, and its non-volume-variable portion, $(1-\varepsilon_j)C_j$:

$$C_j = \varepsilon_j C_j + (1-\varepsilon_j)C_j.$$

[23] The mathematical presentation in this section is derived from Bradley, Colvin, and Panzar (1999).

Note that the non-volume variable portion may be a combination of any component fixed cost and what Bradley, Colvin and Smith (1993) termed the component's "inframarginal costs."[24] The non-volume-variable costs are also known as "institutional" costs.[25]

Recall that a goal of the costing methodology is to calculate marginal costs for products, not components. Therefore, another step is needed to relate volume variable costs to individual products. This is done by exploiting the relationship between the component's cost driver and the volumes that require consumption of the driver. That relationship is captured by the elasticity of the driver with respect to volume, σ_{ij}:[26]

$$\sigma_{ij} = \frac{\partial D_j}{\partial V_i}\frac{V_i}{D_j}.$$

With this elasticity, one can now calculate the volume variable cost in component "j" caused by volume "i":

$$VVC_{ij} = \varepsilon_j C_j \sigma_{ij.}$$

Unit volume variable cost for the i^{th} product is found by dividing the product's total volume variable cost by its total volume:

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[24] See, Bradley, Michael, D., Colvin, Jeff and Smith, Marc (1993), "Measuring Product Costs for Ratemaking: The United States Postal Service," in Regulation and the Nature of Postal and Delivery Services, M.A. Crew and P.R. Kleindorfer eds.,1993 , Kluwer Academic Publishers.

[25] In activity based analyses these costs are known as "product sustaining" or "enterprise sustaining" costs.

[26] In practice, the elasticity σ_{ij} is typically not directly measured, but rather approximated by a distribution key share.

$$UVVC_{ij} = \frac{\varepsilon_j C_j \sigma_{ij}}{V_i}.$$

The formulation makes it very easy to demonstrate the equivalence of unit volume variable costs and marginal costs:

$$UVVC_{ij} = \frac{\frac{\partial C_j}{\partial D_j}\frac{D_j}{C_j} C_j \frac{\partial D_j}{\partial V_i}\frac{V_i}{D_j}}{V_i} = \frac{\partial C_j}{\partial V_i}$$

The product's overall unit volume variable, or marginal, cost is just the sum of its component marginal costs.

In addition to calculating marginal costs, the PRC/Postal Service methodology also includes the calculation of incremental costs.[27] As explained above, incremental costs, in a multiproduct firm, are the analog of a product's total cost in a single-product firm and represent the total cost caused by a product (or group of products) in that multiproduct firm. As a result, any attempt to add costs to a product's (or group of products') incremental cost necessarily involves an arbitrary assignment of cost that is not based upon cost causality. Consequently, it is widely recognized that incremental costs are the right cost concept when checking for cross-subsidization. For example,

[27] While the methodology includes the methodology for calculating incremental cost for individual competitive products, the Postal Service currently calculates incremental costs for the group of competitive products. See, Response of the United States Postal Service to Question 1 of Chairman's Information Request No. 6, Docket No. RM2016-2.

the Commission has approved the use of incremental cost in testing for cross-subsidization of competitive products:[28]

> The Commission commends the Postal Service for its efforts to implement an incremental cost analysis to test for competitive product cross-subsidies. As reflected in the Postal Service's proposed formulae, if marginal costs decline continuously, incremental costs will be higher than attributable costs. Therefore, substituting the Commission analysis for the costs for the former would raise the competitive product cost floor used to determine compliance with U.S.C. 3633(a)(1) to test for cross-subsidies. Bringing the cost floor closer to actual incremental costs will help ensure that there is an economically efficient incentive for entry by competitors who might otherwise be unable to participate in postal markets.

Conceptually, the incremental cost for a product (or group of products) can be calculated by comparing the Postal Service's total cost before the product is added to the mix with the Postal Service's total cost after the product is added to the mix. For Product "A", the incremental cost is given by:

$$IC_A = C(V_i) - C(V_i - V_A).$$

The PRC/Postal Service methodology calculates marginal costs by calculating each product's marginal cost in the individual cost components. The related component cost elasticities and marginal costs are key inputs in the incremental cost calculation. Consequently, the calculation of incremental cost proceeds at the component level. The first step is to identify, for each component, how much of the cost driver is added because of the provision of the product being examined. This is also done by

[28] See, Postal Regulatory Commission, Order No. 399, Order Accepting Analytical Principles Used In Periodic Reporting (Proposals Twenty-Two Through Twenty-Five), January 27, 2010.

comparison. The amount of the driver required for Product A is the difference between the amount of the driver used before Product A was provided and the amount of driver required when all products are provided:

$$D_{jA} = \delta_j(V_i) - \delta_j(V_i - V_A).$$

The incremental cost for Product A in that component is the sum of any product specific cost for the product (in that component) and the additional variable cost caused by providing the product:

$$IC_{jA} = F_{jA} + \gamma_j\left(D_j\right) - \gamma_j\left(D_j - D_A\right).$$

The product incremental cost is just the sum of the component incremental costs.

Incremental costs and marginal costs are precisely related. Incremental cost is just the sum of the marginal costs for all units produced. Consequently, the calculation of incremental cost requires identifying the portion of inframarginal costs that are caused by the provision of an individual product (or group of products). Also, because it is based upon the actual causality between individual products and their resulting costs, incremental cost avoids the arbitrary and inaccurate assignment of cost to products like is contained in the UPS proposals.

Implementing this calculation requires recognizing that incremental costs are, by definition, the costs of adding any individual product (or groups of products) to the firm's vector of outputs. This is true for <u>every</u> service the firm provides, and there is no "ordering" in the definition of incremental costs. That is, market dominant products do not come "before" competitive products, nor competitive products "before" market dominant products. It is erroneous to assert that, in any cost component, some products have higher driver marginal costs than others—all products in a specific activity are produced simultaneously and the calculated driver marginal cost applies equally to all products. In sum, the calculation of incremental costs for each and every product (or group of products) starts at the current level of volume. This is because incremental cost measures the additional cost a product (or group of products) causes when it is added to the Postal Service's current mix of products.

The application of the multiproduct firm cost concepts provides the cost measurements required for pricing and for checking for cross-subsidization. The PRC/Postal Service costing methodology is designed to produce the two cost measurements—marginal cost and incremental cost—that the Postal Service and the Commission need to make informed pricing decisions and regulatory cross-subsidy tests. This has been recognized and endorsed by external experts:[29]

> The volume-variable or marginal product costs currently reported by the USPS cost system should be used — after the product definition modification required by PAEA— to ensure that the competitive products cover their attributable costs. The reported incremental costs should be used to ensure that cross-subsidization of the competitive products by the market-dominant products is not occurring.

[29] See, U.S. Department of Treasury, "Accounting Principles and Practices for The Operation of the United States Postal Service's Competitive Products Fund," December 2007 at 32.

Contrary to the UPS proposals, there is no need to add any additional costs to either marginal cost or incremental cost. Each has a well-defined role in economic theory and is sufficient for the role it plays in the pricing and regulatory processes.

V. UNDERSTANDING SHAPLEY VALUES

UPS, based upon the expert report of Dr. Neels, proposes that the Commission use a method of cost allocation which UPS and Dr. Neels claim is loosely based on the application of the game theory result known as Shapley values. Although I will address the details of the UPS application approach later in this report, it is first useful to gain an understanding of what Shapley values are and their applicability to common cost allocations.

To get a sense of what Shapley values are, suppose the Postal Service decided it was going to allocate all of its common costs to individual products.[30] One approach to allocating those costs would be to allow the product managers to bargain over the allocation. That is, the managers would end up choosing the method of allocation by bargaining amongst themselves to determine how much common cost was allocated to each product. Such an approach can be analyzed with a branch of mathematics known as game theory.

One important subset of game theory is the study of "cooperative" games in which participants work together to find the best solution (as opposed to working just for

[30] This is a hypothetical thought experiment. The Postal Service does not need to allocate all of its common costs to develop the appropriate cost measures for setting prices and testing for cross-subsidy.

themselves). Shapley values result from cooperative game theory and represent a numerical evaluation of the benefit to participants from playing a cooperative game.

In the context of cost allocation, a Shapley value is the amount of common cost allocated to an individual product, such that its product manager is indifferent between taking that allocation or?and determining the allocation though (costless) cooperative bargaining. If product managers are risk-neutral, the Shapley value will be the average amount of cost allocated to the product across all of the different bargaining outcomes.[31] For example, one such bargaining approach would be to artificially assume that the products are made in sequential order (instead of simultaneously) and then calculate the average of the incremental costs for each product across all possible orderings.

The theoretical attraction of Shapley values is that they, like incremental costs, produce costs which lead to subsidy-free prices. Also, application of Shapley values can lead to mathematically computable outcomes that avoid the need for complex bargaining. However, it is not clear that the allocation of common costs is necessarily one of those circumstances:[32]

> Shapley's original formulation of the problem of defining a value for games characterized by the Shapley value as the unique function obeying a certain set of axioms. However,

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[31] A person is risk neutral if he or she does not consider the risk associated with uncertain outcomes when making decisions. For example a risk neutral person would be indifferent between the following two assets. Asset A has a one-half chance of paying 7 percent return and a one-half chance of paying a 9 percent return. The expected return is thus 8 percent. Asset B has a one half chance of paying a 20 percent return and a one-half chance of paying 4 percent return. It also has an expected return of 8 percent. A risk neutral person would consider these two assets to be equivalent.

[32] See, Roth, Alvin E. and Verrecchia, "The Shapley Value as Applied to Cost Allocation: A Reinterpretation," Journal of Accounting Research, Vol. 17, No. 1, 1979 at 296.

> these axioms have proved difficult to interpret in a compelling way from the point of view of cost allocation. [References omitted.]

The application of Shapley values to common cost allocation requires making strong assumptions about the preferences of product managers. If these assumptions are not valid, the theoretical benefits associated with using Shapley values dissipate:[33]

> Under Assumptions 1-3 of Section 2.3, the Shapley value represents managers expected utility for bargaining, and therefore each manager would be indifferent between having his department charged its gross benefit less its Shapley value or bargaining to an uncertain outcome. In this sense, the Shapley value represents a fair, equitable, neutral, and costless surrogate for allowing managers to bargain over how costs will be allocated. Of course, this conclusion is predicated on the fact that managers' preferences obey certain assumptions. We would not expect all managers to have a neutral attitude toward both probabilistic and strategic risk in all situations. But there may be circumstances in which a firm would find it convenient to assume that managers behaved as if their preferences obeyed these assumptions, and in these circumstances the justification for using the Shapley value as a cost assignment method would be clear. However, if a firm chose to assume otherwise, the Shapley value might not yield an entirely appropriate cost allocation scheme. [Emphasis added.]

Perhaps even more importantly, it is essential to keep in mind that Shapley values come in to play only after a decision has been made to arbitrarily (or non-causally) assign common costs to products. Shapley values are just one of an infinite number of possible allocations of common costs and do not depend upon or provide a causal link between products and their assigned common costs.

Moreover, it is of very little value that the resulting costs provide cost floors for subsidy-free prices, because the Shapley costs are above true incremental costs.

[33] Id. at 301.

Because the incremental costs already provide cost floors for subsidy-free prices, producing any costs that are above incremental costs will also provide subsidy-free prices. For example, because they are above incremental costs, Dr. Neels' pseudo-Shapely costs provide cost floors for subsidy-free prices just as true Shapley costs would. In fact, any arbitrary allocation scheme that assigns additional common costs to correctly calculated incremental costs would provide cost floors for subsidy-free prices. But the various sets of subsidy-free price floors are not economically neutral, and harm can arise from using misallocated costs.

The harm arises because misallocated costs send the wrong signals for pricing, and Shapely-based costs may lead to inefficient outcomes. That is, Shapley-based costs can distort the true incremental cost signal by setting too high of a cost floor for subsidy-free pricing, and thus lead to suboptimal outcomes:[34]

> Economic theory and common sense are absolutely clear that the relevant costs for pricing decisions are the incremental costs. So long as the marginal revenue derived from the sale of one or more unit[s] is greater than the incremental cost of that unit, a profit-maximizing firm would want to sell that unit. Likewise, from a public policy perspective, so long as the marginal benefit (price) to consumers is greater than the incremental cost, society is made better off by producing and consuming the additional unit in question. While the resulting quantities demanded may be different, the principle is the same: the incremental benefits to the firm/public (prices) should be compared with marginal/ incremental cost, not fully allocated costs. [Footnote omitted.]

By leading to prices that are too high, excessive cost allocation could lead to the loss of volume and the associated contribution. This is particularly true for products that

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[34] See, Beauvais, Edward C and Sheffield, Virginia K., "Public Policy for A Multiproduct Firm," Utilities Policy, Vol. 3, No.4, October 1993, at 303.

participate in a competitive market. The resulting higher prices would hurt consumers and, combined with the resulting loss of volume, would likely lead to lower utility for consumers. Moreover, such distortionary pricing signals could even hurt consumers of market dominant products as they would be stuck with replacing the lost contribution caused by excessive prices in competitive product markets:[35]

> After all, it is thought, if more costs can be attributed to certain classes of mail, there will be fewer institutional costs left to be borne by captive mailers. Unfortunately, since the attribution process cannot (and should not) take account of demand factors, an effort to attribute a greater and greater proportion of costs will ultimately (and ironically) work to disadvantage captive mailers by requiring them to cover the institutional costs formerly covered by mail volumes inefficiently driven off the system due to inappropriately high attributable cost floors.

In sum, allocating common costs based upon Shapley values suffers from the widely recognized weaknesses of fully distributed costing:[36]

> Shapley values are not free of arbitrary assignments of costs. The Shapley value formula, while yielding a unique solution, contains a weighting scheme that is necessarily arbitrary. The Shapley value allocates common costs, which are by their nature unattributable to individual services. The mainstream of published economics, when discussing the shortcomings and dangers of fully distributed cost (FDC) methods, does not provide a special dispensation for Shapley values; the mainstream of the literature provides for unequivocal rejection of all forms of FDC.

[35] See, Rebuttal Testimony of John C. Panzar On Behalf of the United States Postal Service, USPS-RT-2, Docket No. MC95-1 at 17.

[36] See, Larson, Alexander C., "Inside the Black Box: A Policymaker's Guide to Shapley Values and Telecommunications Cost Allocations," Utilities Policy, Vol. 4, No.4, October, 1994, at 306.

Despite their theoretical niceties, Shapley values are virtually never used for actual cost allocations.[37] In part, this is because properly calculating them can be incredibly computationally intensive. For a firm with just 15 products, calculating the Shapley costs would require over 1.3 trillion incremental cost calculations. For the Postal Service, which has at least 34 different products, calculating Shapley costs would require at least 2.95×10^{38} cost calculations. Such an effort would be totally infeasible. To provide a sense of the size of that number of calculations, consider that astronomers have estimated that there are 100 billion to 1 trillion galaxies, each with 100 billion to 1 trillion stars, leading to 10^{22} to 10^{24} stars in the universe.[38]

In sum, Shapley values are not needed to protect against cross-subsidization in multiproduct firms, can be extremely burdensome to calculate, and can lead to distortionary prices. They turn out to be of little value in allocating costs in network industries:[39]

> [F]ar from being a panacea for solving the difficult problem of allocating costs or setting efficient telecommunications prices, Shapley values make no contribution at all towards solving this challenging problem. Though Shapley values may have a legitimate application in other industries, they

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[37] For example, in response to Chairman's Information Request No.4, UPS could not cite a single instance in which Shapley values were used in a regulatory proceeding. UPS could only offer three instances over a thirty-year period in which the use of Shapley Values were even proposed. See, United Parcel Service, Inc.'s Response to Chairman's Information Request No. 4, Docket No. RM2016-2 at 6.

[38] See, http://www.esa.int/Our_Activities/Space_Science/Herschel/How_many_stars_are_there_in_the_Universe.

[39] See, Larson, Alexander C., "Inside the Black Box: A Policymaker's Guide to Shapley Values and Telecommunications Cost Allocations," Utility Policy, Vol. 1, No.4, at 303.

> are impossible to use in a network-based industry as complicated as telecommunications: hence they offer no realistic solutions to difficult costing or pricing problems. If mandated in public utility law or policy, they would comprise a significant cost of regulatory compliance with no counterbalancing benefit.

VI. THE ANALYSIS SUPPORTING UPS PROPOSAL ONE SUFFERS FROM DISQUALIFYING ERRORS.

Based upon the expert report submitted by Dr. Kevin Neels, United Parcel Service proposes to allocate inframarginal costs to products based upon their relative proportions of volume variable costs.[40] Unfortunately, Dr. Neels's analysis suffers from serious errors in both its conceptual basis and in its computational algorithm. Dr. Neels justifies his proposal on the basis of three assertions, all of which turn out to be in error.

First, Dr. Neels argues that inframarginal costs should be allocated to products because they are variable costs.[41] If Dr. Neels were analyzing a single-product firm, this point would be correct, but as explained above, in a multiproduct firm, the fact that cost is variable, does not, by itself, justify its attribution to any specific product. In multiproduct firms, there can be variable costs which are not caused by any individual products. To justify the attribution of costs to products in multiproduct firms, a causal link must be established as is done for marginal and incremental costs.

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[40] See, Proposal One – A Proposal to Attribute All Variable Costs Caused by Competitive Products to Competitive Products Using Existing Distribution Methods, Docket No. RM2016-2, at 1.

[41] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 16. This argument has been repeated by UPS in its proposals. For example see, Proposal One – A Proposal to Attribute All Variable Costs Caused by Competitive Products to Competitive Products Using Existing Distribution Methods, Docket No. RM2016-2, at 4 and Proposal Two -- A Proposal To Correct the Misclassification of Fixed Costs, Docket No. RM2016-2, at 5.

Second, Dr. Neels claims that inframarginal costs can be reliably shown to be caused by individual products.[42] This assertion is wrong because it fails to account for the fact that postal products are produced simultaneously. Dr. Neels argues that inframarginal costs are based upon a cost driver and cost drivers can be related to products through distribution keys. From these two claims he asserts that there must be a reliable link between inframarginal cost and products. But this assertion misses a key point. Inframarginal costs can arise from common production in which the cost driver is simultaneously shared among one or more products. In Dr. Neels's transportation example, TRACS data are used to distribute volume variable costs to products (in order to calculate marginal costs) but that does not mean that all inframarginal costs are "assignable" to individual products. Recall that inframarginal costs are the difference between total costs and volume variable costs and can include common costs, which are not attributable to any products. The only way that an inframarginal cost is assignable to a product is if <u>all</u> of the change in the cost driver is due to a change in just one product, as when computing incremental costs. Dr. Neels's proposed procedure relies upon a simultaneous reduction in all products, in which case one cannot assign the reduction in the cost driver to any individual product. This is to say, the only part of inframarginal costs caused by individual products is the portion that would be included in the product's incremental cost.

Third, Dr. Neels asserts that failure to attribute inframarginal costs could distort competition. In fact, as shown above, just the opposite is true. Dr. Neels presents no economic or mathematical analysis to support this assertion, but rather just claims the

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[42] <u>Id</u>. at 17.

problem exists because the Postal Service gets an "unfair" advantage by starting its pricing exercise with marginal costs. Of course using marginal costs as a starting point for pricing provides no unfair advantage for the Postal Service as all firms, could (and should) start their pricing exercises with marginal costs. As succinctly summarized by Professor Panzar:[43]

> The case for the use of marginal costs as the basis for rate-making are well established in both the economics literature and before the Postal Rate Commission.

Dr. Neels cannot seriously question the calculation and use of marginal costs, so he must rather question the nature of the Postal Service's marginal cost, saying the Postal Service has an unfair advantage because its economies of scale and scope provide it with low marginal costs.[44] In this argument, Dr. Neels makes two mistakes. First, Dr. Neels confuses costing decisions with pricing decisions. Dr. Neels acts as if the Postal Service sets its prices equal to its marginal costs. It does not; rather the Postal Service uses marginal costs as the starting point for setting prices and then sets prices above marginal cost subject the constraint of its price cap.[45] To break even, the Postal Service must recover all of its costs, including its inframarginal costs; its rates, collectively, must be high enough to enable it to do so. If the Postal Service gains any benefit from the efficiency of its network, it arises in the form of lower total costs.

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[43] See, Direct Testimony of John C. Panzar on Behalf of the United States Postal Service, USPS-REM-T-2, Docket No. R90-1 (Remand) at 4.

[44] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 18.

[45] Only market dominant products are subject to the price cap but both market dominant and competitive products have mark ups.

Second, Dr. Neels again fails to recognize that the Postal Service is a multiproduct firm and proceeds to analyze it as if it were a single-product firm. Consider his following statement:[46]

> This practice understates the costs associated with all units except for the last unit, and yields cost estimates that are significantly below average variable costs. The huge advantage granted to the Postal Service in the form of lower average variable costs is amplified, allowing the Postal Service to price competitive products below average variable cost. [Emphasis added.]

Section III, above, demonstrates that average variable cost does not exist for a multiproduct firm like the Postal Service, so Dr. Neels's analysis is misplaced. Perhaps what Dr. Neels meant to say is that in a multiproduct firm with economies of scale and scope, a product's marginal cost will be below its average incremental cost. As a result, such firms should calculate the average incremental costs of their products to determine if their revenues are sufficient to ensure they are producing positive contributions. In sum, the calculation of marginal cost and incremental cost provides all of the cost measures the Postal Service needs for efficient pricing that is in compliance with the law.

Dr. Neels then attempts to use Shapley values to allocate inframarginal costs to individual products.[47] Dr. Neels recognizes that, as discussed above, calculating the Shapley values would require a huge number of calculations and is simply not feasible. Thus, Dr. Neels proposes a shortcut.[48] Dr. Neels asserts, without any analytical or

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[46] Id. at 19.

[47] Id. at 22.

[48] Id. at 27.

mathematical justification, that one can avoid the computational complexity of calculating Shapley values by assuming that the proportion of a cost driver associated with each product is randomly distributed under the component's (cost driver) marginal cost curve. Then, he asserts, one can accurately distribute inframarginal costs on the basis of relative driver proportions, like one does for volume variable cost, and still retain the desirable properties of Shapley values without the otherwise insurmountable computational burdens.[49]

Unfortunately for Dr. Neels's analysis, his shortcut fails to recognize a fundamental difference between the two exercises. The distribution of volume variable cost to products is linear, so it does not matter where a product's portion of the driver falls along the volume variable cost curve. This is because, along that function, the marginal cost is the same for all units. However, the incremental cost calculation requires computing costs along the component's (cost driver) marginal cost function, which is nonlinear. The marginal cost for a unit of the driver changes nonlinearly as the total amount of the driver used changes. In this circumstance, it does matter where a product's part of the driver falls under the marginal cost curve because the associated marginal cost is different at different places along the curve. That is why the Shapley Value approach requires calculating incremental costs for all possible orderings of products. As a result of this key difference, using the cost driver distribution key to assign inframarginal costs to products will not replicate the Shapely values, as Dr. Neels asserted.

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[49] Id. at 28.

This result can be demonstrated with a simple three-good example.[50] When there are just three goods being considered, there are only six different orderings of those goods, so the computation of Shapley values is straightforward. To be consistent with Dr. Neels's approach, a constant elasticity function is specified in which the total cost in the component (C) is a function of the total amount of the driver (D) used in the component:

$$C_j = \alpha D_j^{\beta}$$

In the numerical example, α is 200 and β is 0.5. The total amount of the driver is 520 units, causing a component total cost of $4,560.70. Finally, there are three products, labelled A, B and C. This distribution of the cost driver across the three products is given in Table 1.

Table 1

Driver Proportions for Shapley Values Example

Product	**Amount of Driver**	**Proportion of Driver**
A	70	13.5%
B	150	28.8%
C	300	57.7%
Total	520	100.0%

There are six different orderings of the three products that need to be considered. The six orderings are given in Table 2.

[50] The model and calculations for this three-good example are provided in USPS-RM2016-2/1. A mathematical demonstration of these points is presented in the Appendix to this report.

Table 2

The Set of Orderings for the Shapley Values Example

Products	**Ordering 1**	**Ordering 2**	**Ordering 3**	**Ordering 4**	**Ordering 5**	**Ordering 6**
First	A	A	B	B	C	C
Second	B	C	A	C	A	B
Third	C	B	C	A	B	A

The Shapley cost for each of the product is found through calculating how much additional cost arises from adding the product to the mix in each of the orderings. For example, for the first ordering, the additional cost of Product C is the difference between the total cost of producing products A, B, and C together ($4,560.70) and the total cost of producing products A and B together ($2,966.48), or ($1,594.22). Completing the exercise yields six additional costs for each product. Under the assumption that all orderings are equally likely, the Shapley value is just the average of the six additional costs.

Dr. Neels's proposed costs do not come from this process, but instead come from multiplying the proportion of the driver for each product by the total amount of inframarginal cost.[51] In the example, total inframarginal costs are given by (1-β) C or $2,280.35. The portion of inframarginal cost assigned to each product, using Dr. Neels's method, is just their driver proportions multiplied by that value. This results in inframarginal cost allocations of $306.97 to Product A, $657.79 to Product B, and

[51] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 28.
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$1,315.59 to Product C. Because the component's variability is 50 percent, the inframarginal cost assignments simply equal each product's volume variable costs.

This fact highlights another characteristic of Dr. Neels's shortcut approach. Because the same driver proportion is applied to both the volume variable and non-volume variable costs, Dr. Neels's approach is mathematically equivalent to simply multiplying the component's total cost (regardless of variability) by each product's driver proportion. In other words, for the analyzed components, Dr. Neels's approach is actually a simple Fully Distributed Cost (FDC) allocation scheme based upon relative driver proportions. Table 3 demonstrates that Dr. Neels's shortcut method does not produce the Shapley value costs.

Table 3
A Comparison Shapley Values and the Results of
Dr. Neels's Approximation

Product	Shapley Values	Dr. Neels's FDC Allocation
A	$814	$614
B	$1,400	$1,316
C	$2,347	$2,631
Total	$4,561	$4,561

This result also demonstrates that the costs calculated using Dr. Neels's proposed allocation method do not have the theoretical characteristics associated with Shapley values, and are, instead, simply the results of an arbitrary FDC cost allocation scheme.

In addition to the conceptual infirmities in Dr. Neels's proposed approach, he makes a serious computational error that causes him to overstate the amount of inframarginal costs that his proposed method attributes to products. Dr. Neels states that he adopted Dr. McBride's approach to calculating inframarginal costs (although Dr. McBride does not assign those costs to products), apparently without independently validating the methodology.[52] Review of Dr. McBride's work reveals that in doing his calculations, his approximation technique for certain components that contained multiple cost pools inadvertently id not account for certain cost pools with zero variabilities. Instead, Dr. McBride incorporated the costs from those cost pools with other cost components, with positive variabilities into the cost components.[53]

Dr. McBride stated that he did not evaluate the incremental cost model at the cost pool level as USPS did in R2005-1, but rather at the more aggregated component level.[54] In determining how to treat a component, he reviewed the cost pool allocations within that component, and applied the constant elasticity method to the component if the majority of cost pools in the component were of this category.[55] However, Dr. McBride apparently did not realize that the R2005-1 filing did not include the cost pools that had zero variabilities, because they were not applicable for incremental cost calculations. This caused him to treat costs with zero variabilities as if they had positive

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[52] Id. at 20.

[53] The components for which this occurred are: Component 40, Window Service; Component 74, Custodial Personnel; Component 81, Contract Cleaners; Component 79, Plant and Building; Component 314, Fuel & Utilities; Component 176, Custodial & Building; Component 194, USPS Security Force; Component 75, Operating Equipment Maintenance; Component 184, Equipment Parts and Supplies; Component 232, Equipment Depreciation.

[54] See, McBride, Charles, "The Calculation of Postal Inframarginal Costs," manuscript, at 7.

[55] Id.

variabilities and combine those costs with other cost pools. He then applied the constant elasticity method to the combined cost. In other words, Dr. McBride calculated inframarginal costs for components in which inframarginal costs do not exist under the constant elasticity method.[56] As a result, Dr. McBride inadvertently overstated the amount of inframarginal costs calculated by this method.

Because Dr. Neels directly adopts Dr. McBride's methods, he repeats the mistake and also overstates the inframarginal costs for FY2014. In particular, using the constant elasticity method, Dr. Neels calculates inframarginal costs of $13.4 billion rather than the correctly calculated value of $10.8 billion.[57] Thus, Dr. Neels's "new" competitive costs are just 1.14 times the actual competitive volume variable costs, not the larger 1.25 times he claims.

There is another important computational issue which is not addressed by Dr. Neels. For the purpose of calculating incremental cost, the Postal Service assumes that cost components can be modeled as if they had a constant elasticity cost function.[58] Instead of using the actual estimated cost functions, the incremental cost model uses just the elasticities from those functions, and assumes a constant elasticity form. This approximation is acceptable for calculating incremental costs, because research has

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[56] Dr. McBride reported looking at the accuracy of his approximation approach for only one cost pool, and concluded the approximation error was "negligible" for that cost pool. See, McBride, Charles, "The Calculation of Postal Inframarginal Costs," manuscript, at 8. However, as shown in USPS-RM2016-2/1, the approximation approach actually causes large errors for other cost pools.

[57] The correct approach is to calculate inframarginal costs only for cost pools with positive variabilities. The correctly calculated inframarginal costs under the constant elasticity method are provided in USPS-RM2016-2/1.

[58] See, Direct Testimony of Michael D. Bradley on Behalf of the United States Postal Service, USPS-T-22, Docket No. R2000-1 at 24.

shown that the approximation is acceptably accurate at the volume levels used to evaluate the underlying functions.[59]

However, it is not clear that the approximation is accurate at volumes which are very different from the levels at which the underlying functions are evaluated. For example, Dr. Neels's approach requires calculating inframarginal costs at near-zero volumes, and the property of the approximation at those extremely low volumes is unknown. Implicitly, Dr. Neels is assuming the approximation is acceptably accurate over the total range of volume, but in reality he has produced no evidence suggesting that this is the case. To the degree approximation is inaccurate, Dr. Neels's computations could produce substantial errors.

In sum, Dr. Neels's analysis to support UPS Proposal One contains some serious flaws that disqualify it from being an acceptable basis for changing an established costing methodology. Its cost allocation is arbitrary, it does not actually produce Shapley values, it is based upon untested assumptions, and it includes computational errors. However, even if it were correct, it would be superfluous. Dr. Neels's calculated product costs will lead to subsidy-free prices simply because they exceed incremental costs, but are unnecessary because incremental costs already lead to subsidy-free prices.

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[59] See, Bradley, Michael D., Colvin, Jeff and Panzar, John C., "Issues in Measuring Incremental Cost in a Multi-Function Enterprise," in Managing Change in The Postal and Delivery Industries, Michael Crew and Paul Kleindorfer (eds.), Kluwer Academic Publishers., 1997, 3-21.

VII. THE ANALYSIS SUPPORTING UPS PROPOSAL TWO FAILS TO MEET THE BASIC STANDARD FOR AN ACCEPTABLE COSTING METHODOLOGY.

UPS Proposal Two asks the Commission to require the Postal Service to reclassify component “fixed” costs as “variable” and then to somehow attribute the “variable” portion to individual products.[60] To support UPS Proposal Two, Dr. Neels presents a three-step process to assign additional amounts of institutional cost to competitive products, as follows:[61]

1. Dr. Neels claims that the Postal Service has identified certain cost components as containing “fixed costs” when they actually contain, he believes, misclassified “variable” costs.

2. Dr. Neels runs a set of simple regressions relating these components’ “fixed” costs to a measure of aggregate volume to see which ones are “really” fixed and which are “hidden variable” costs. These time series regressions are based upon only 8 annual observations.

3. For cost components he deems “hidden variable,” Dr. Neels allocates the institutional costs to products based upon the products’ shares of attributable costs in the previous year.

As demonstrated below, each step of this proposal contains errors which are sufficiently serious to render the proposal invalid. Consequently, Proposal Two does not meet the basic standards for an acceptable change in costing methodology.

The first step in this process is faulty because it relies upon a classification of costs made by neither the Postal Service nor the Postal Regulatory Commission. Dr. Neels does not present an independent review of the individual cost components to

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[60] See, Proposal Two -- A Proposal To Correct the Misclassification of Fixed Costs, Docket No. RM2016-2, at 1.

[61] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 31.

determine which the Postal Service identified as "fixed" and which the Postal Service identified as "variable."[62] Rather, he appears to rely upon the analysis of cost components put forth by Dr. McBride in an earlier manuscript.[63] Yet Dr. McBride's analysis has never been critically reviewed or validated and, thus, potentially includes cost misclassifications. The fact that Dr. McBride may have labeled the costs in a particular component as "fixed" costs does not mean that they actually are fixed or that the Postal Service views them to be fixed.

A review of the components identified as "fixed" by Dr. Neels' reveals that his analysis contains substantial misclassifications. For example, consider the two largest (in terms of cost) components that Dr. Neels classifies as "fixed" and then converts to "hidden variable." The largest component is Component 202 (in Cost Segment 18), which contains Current Year Annuitant Health Benefits. It contained $1.38 billion in institutional costs in FY2014.[64]

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[62] Id. at 40.

[63] See, McBride, Charles, "The Calculation of Postal Inframarginal Costs," manuscript, at 10.

[64] Component 202 is the "current year" portion of Cost Segment 18.3.6, Annuitant Health Benefits & Earned CSRS Pensions. In FY2014, Cost Segment 18.3.6 had accrued costs of $8.685 billion, which is the sum of the $5.7 billion payment owed for the Postal Retirees Health Benefit Fund, as per PAEA, and $2.985 billion payment for health benefits for current retirees. The basis for determining the amount of current-year costs is to identify the benefits earned during the fiscal year by current employees. The current year costs for FY2014 or Component 202 cost is the sum of retiree health benefits earned during FY2014 of $2.606 billion and CSRS retirement benefits earned by CSRS employees equal to $0.547 billion, totaling $3.153 billion. These current year costs, Component 202, are driven by the total number of current career employees (and current CSRS employees) and are earnings of current employees in the same way as other salaries and benefits that are included in cost segments 1-13, 16, 18.1 and 19. For additional details see, Summary Description of USPS Development of Costs by Segments and Components, FY 2014 at 18-1.

Component 202 is part of service-wide personnel benefit costs which are included in Cost Segment 18.3. These service-wide benefit costs are part of salaries and benefits paid to employees in just the same way as labor costs in Cost Segments 1-13, 16, 18, and 19 and thus have the same variability and distribution key as those costs.

That is, these costs are related to the total number of current career employees and are earnings of current employees in the same way as other salaries and benefits. This means the component's costs are variable in the sense that they would be avoidable if volume (and Postal Service staffing) were hypothetically reduced to zero.

But the fact that they are variable costs does not imply that they should be attributed to products. As explained in Section II above, in a multiproduct firm, it is typical to have variable costs that are not part of the marginal or incremental costs of any individual product(s).

The second largest component is Component 33 (in Cost Segment 2) which contains costs for "Other" Supervisors and Technicians. In FY2014, it contained $419.847 million in institutional costs.[65] These costs arise from work by professional and technical personnel, including general administrative work. This work includes activities such as customer service representatives, accounting and industrial engineers. While these labor costs are variable, they are also common to all products.

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[65] This component is over 99 percent institutional. A very small portion of these costs are considered product specific to international mail and services.

Review of Postal Service documentation makes this clear. The FY2014 Summary Description states:[66]

> The activities performed by the technicians included in the technical personnel and other supervisory activities group do not involve supervision and are not significantly affected by the number of craft employees. Instead, these technicians are involved in such work as industrial engineering, address information system analysis, systems examination, and similar technical activities. Accordingly, the number and costs of these technicians depend largely on factors of management design, organizational structure, and service standards and are classified as institutional.

As with the costs in Component 202, these common costs are not caused by any individual products and cannot and should not be attributed to products.

The fact that these costs are misclassified as "fixed" by Dr. Neels renders superfluous his subsequent statistical analysis. It is of no value to attempt to identify these costs as "hidden variable" as they have always been considered "unhidden" variable costs. But the key point is, contrary to Dr. Neels's assertion, the fact that they are variable does not provide a basis for attributing them to products. Because they are common costs, they do not vary with changes in the volumes of individual products and would not be appropriately included in any product's marginal costs. Adding to a product's volume does not cause these costs to increase proportionally, hence these components include institutional (or non-volume-variable) costs.

Based upon his misunderstanding of the nature of this set of cost components, Dr. Neels attempts to estimate a set of simple regressions, using time-series data,

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[66] See, Summary Description of USPS Development of Costs by Segments and Components, FY2014 at 2-5.

which purport to test for the “fixity” of the components’ institutional costs.[67] He does this both for overall total “fixed” costs and component level “fixed” costs. This approach has two conceptual problems. First, as explained above, many of the components that Dr. Neels claims contain fixed costs actually contain variable but institutional costs. Second, even if a cost is fixed with respect to volume, it is not necessarily fixed with respect to time. Thus, a time-series regression of fixed cost on volume could produce a spurious correlation because the change in fixed cost was actually caused by an omitted variable.

While these conceptual flaws should be disqualifying by themselves, Dr. Neels’s methods also have serious implementation problems which include inadequate model specification, insufficient data, and a lack of proper econometric practice.

A first specification problem comes from difficulties in constructing the independent variable to be used in the simple time-series regressions. As discussed above, producing a single measure of output for a multiproduct firm necessarily requires “mixing apples and oranges.”[68] The resulting measure of aggregate output is subject to aggregation problems which can render the measure misleading, if not meaningless. These problems are magnified when one attempts to construct a value of aggregate output through time, as Dr. Neels does, because the variable construction must now account for changes in product heterogeneity through time. This type of problem

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[67] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 36.

[68] See, Baumol, William J., Panzar, John C., and Willig, Robert D., Contestable Markets and the Theory of Industry Structure, Harcourt Brace Jovanovich, 1987, at 47.

includes inconsistent product definitions across different years and mix changes over time.

These problems appear to arise for Dr. Neels's weighted volume aggregate. First, Dr. Neels's measure does not apply consistent product definitions across all fiscal years. For example, he did not estimate a weighted volume for Parcel Select that incorporated, for earlier years, the Parcel Select volumes that had been classified as Standard Mail Commercial irregular and machinable parcels, before their reclassification as Lightweight Parcel Select. The resulting Parcel Select weighted volume estimates in earlier years are therefore not measuring the same workload as the estimated volume for FY 2014. Inconsistent product definitions also lead to a material number of zero volume entries for various products. Standard Post provides such an example. Dr. Neels's workload estimates for the fiscal years from FY 2007 through FY 2012 all have zero values for Standard Post. In reality, the volumes were not zero, because the volume that is now Standard Post existed during that time frame as part of the Parcel Post single-piece and Parcel Post CRA product lines.

Second, the comparability of the aggregate output measure suffers through time due to its use of fixed FY2014 attributable cost weights, which do not account for product mix changes over time. Parcel Select and Parcel Return Service are examples of products where the mix has changed significantly over time, with increasing shares of the total volume being dropshipped to delivery unit. In fact, the FY 2008 attributable unit costs for these two products are significantly higher than the FY 2014 attributable unit costs due to product mix changes. A number of market dominant letter and flat products also have seen the product mix change to reflect increased presorting and drop-shipping behavior by mailers. Because of this problem, Dr. Neels's output measure does not accurately reflect relative workloads for every product in earlier fiscal years.

Dr. Neels's model specification problems are exacerbated by the fact that he has only eight observations with which to estimate his model. This is an insufficient amount of data and, by itself, should lead to rejection of the regression analysis. A regression based upon so few data points is fragile, is subject to influential observation problems, has low statistical power, and suffers from fitting the (thin) sample data rather than estimating a true population regression line.

In addition, with only eight data points it is impossible for Dr. Neels to correctly specify the model.[69] He includes only one independent variable, most likely because with such limited data, including other variables could create disqualifying multicollinearity. This means that Dr. Neels is left with a model that says the only determinant of these "fixed" costs, through time, is his weighted volume measure. In other words, he is not allowing or controlling for changes in technology, regulatory shifts, management adjustments, differential labor contracts, or a multitude of other factors that could affect these costs over an eight-year period. At a minimum, these factors could have been controlled for using time trends or period-specific dummy variables in properly specified models (such as component-level models using more granular panel data), but Dr. Neels does not include any such variables.

In addition, Dr. Neels's time period includes the Great Recession years that were tumultuous for the Postal Service, but Dr. Neels does not investigate whether the

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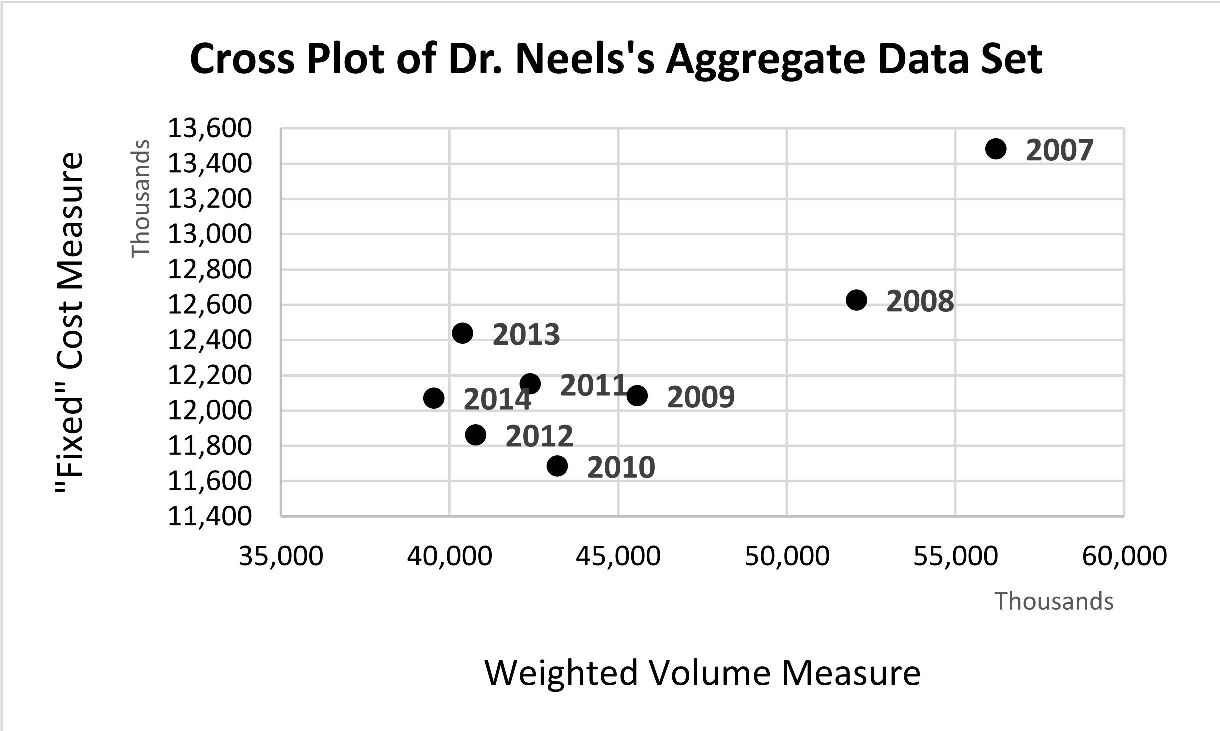
[69] Data limitations apparently precluded Dr. Neels from even considering inclusion of a higher order term, which is normal when estimating cost equations.

estimated coefficients are stable through time. Finally, perhaps because the model is so incompletely specified and there is such limited data, Dr. Neels does not apply any standard econometric tests to the estimated model. He does not test for influential observations, autocorrelation, or stability. In sum, the proffered econometric analysis simply does not reach the standard of acceptable econometric practice.

These are not just theoretical problems with Dr. Neels's analysis. There are also practical consequences that render it unacceptable. First, consider Dr. Neels's aggregate analysis, in which he regresses his measure of inflation-adjusted "fixed" cost against his cost-weighted measure of volume. A simple review of the data used to estimate this regression immediately indicates that there is likely to be a serious problem with the model. Below is a cross plot of Dr. Neels's aggregate dataset comparing his "fixed" cost measures with his weighted volume measures. It clearly shows that FY2007 was an outlier from the rest of the data, and suggests that FY2008 may also be atypical. The existence of outliers is a particularly critical issue for such small datasets because each data point takes on such large importance. In this circumstance just one overly influential observation could be skewing the estimation and providing a spurious regression result.



To test for an overly influential variable, one can simply drop the FY2007 observation and re-estimate the regression. The results of that exercise are presented in Table 4, along Dr. Neels's original results. The table shows that Dr. Neels's apparent finding of a positive and significant relationship between his measure of "fixed" cost and his measure of weighted volume was spurious and was falsely created by the fact that FY2007 was so different from the recent fiscal years. Correcting this major flaw produces just the opposite result: the model estimated on data from FY2008 through FY2014 shows that there is <u>no</u> relationship between fixed cost and volume. Note also that almost all of the apparent explanatory power of Dr. Neels's regression comes from one data point: the distance between the FY2007 data point and the rest of the data. This is an excellent example of the problem of "fitting the sample" with a very small data set in which the estimated model reflects a quirk of the sample, and fails to accurately reflect the true underlying relationship. It also demonstrates the lack of robustness of Dr. Neels's result. In a robust model, dropping one data point would not overturn the model's main result.

Table 4

The Effect of Dropping an Overly Influential Observation

	Dr. Original Neels's Model	**Dr. Neels's Model Dropping FY 2007**
Constant	8,871,956	10,469,119
t-value	8.890	8.418
Weighted Volume	0.076	0.038
t-value	3.463	1.343
R Square	0.667	0.265
Number of Obs.	8	7

The lack of a linkage between Dr. Neels's measure of fixed cost and his volume measure can be confirmed by re-estimating the model on all eight data points but including dummy variables for FY 2007 and FY 2008. The augmented model is specified as:

$$C_t = a + bV_t + c_1 D2007 + c_2 D2008 + \varepsilon_t$$

The results of this estimation, presented in Table 5, show that the model with dummy variables fits the data better than Dr. Neels's original model but again shows that there is no relationship between Dr. Neels's "fixed" cost measure and his aggregate volume measure.

Table 5

Including Year Dummy Variables in Dr. Neels's Model

	Dr. Neels's Model With Dummy Variables
Constant	13,293,854
t-value	5.629
Dummy 2007	1,856,652
t-value	2.174
Dummy 2008	877,840
t-value	1.368
Weighted Volume	-0.030
t-value	-0.527
R Square	0.860
Number of Obs.	8

A last robustness check is provided by the disaggregated volume series provided by Dr. Neels, in which he computes separate volume measures for market dominant products and competitive products.[70] Using Dr. Neels' proposed econometric methodology, one could test to see if the apparent positive relationship between his measure of fixed cost and his measure of volume was coming from both market dominant and competitive products. This could be accomplished by estimating Dr.

[70] See, Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 36.

Neels’ proposed simple linear model separately for the two volume series, and the results are presented in Table 6.

Table 6
Examining Dr. Neels' Proposed Model By Type of Volume

	Dr. Neels's Model For Competitive Volume	**Dr. Neels's Model For Market Dominant Volume**
Constant	12,613,942	10,054,337
t-value	12.785	11.513
Weighted Volume	-0.048	0.058
t-value	-0.324	2.610
R Square	0.017	0.532
Number of Obs.	8	8

While these results are just as spurious as Dr. Neels’s original results, they do appear to suggest that if any volumes are “causing” these fixed costs, it would be the market dominant volumes.

None of the problems associated with Dr. Neels’s aggregate analysis are mitigated by his component-by-component analysis. In some ways, the econometric problems may be more severe. For example, Dr. Neels faces a more difficult specification issue in formulating independent variables in the component-level regressions, because a proper approach to specification would task him with finding or constructing variables that capture the actual cost drivers for component costs with distinct cost structures. But Dr. Neels does not attempt this task and rather mechanically approximates that cost driver for all of the different components with just one of two measures of aggregate volume. In some instances, he uses the previously constructed weighted aggregate volume measure as a proxy for the component level volume or cost driver.[71] In these cases, the specified regression likely suffers from potentially serious measurement error because Dr. Neels is using an aggregate volume measure in an attempt to explain component level costs. In other instances, he multiplies the aggregate volumes by component-specific attributable costs per piece. Even this latter approach is subject to potential measurement errors due to mis-measurement of the true cost driver.

The component-level regressions also suffer from the same econometric difficulties as the aggregate regression, such as omitted variables bias. It was not feasible, however, to review all 88 component cost measurements and to specify a different model for each component. An overall review of the component costs showed that they followed the general pattern associated with the aggregate “fixed” cost measure, falling sharply at the beginning of the period followed by flat growth at the end of the period. In other words the component costs tended to be decreasing through time, but at a decreasing rate. Such a shape is consistent with a quadratic trend, so the following extended version of Dr. Neels’s model was estimated for the each of the 88 components:[72]

[71] This is the same variable that Dr. Neels used in his aggregate fixed cost regression.

[72] The data and programs used to estimate this model, along with the results, are presented in USPS-RM2016-2/1.

$$C_t = a + bV_t - c_1 t + c_2 t^2 + \varepsilon_t$$

Before considering these results, let us step back and consider the framework or approach Dr. Neels uses to consider his results. Dr. Neels takes an unusual approach to evaluating the estimated regression results. Rather than specifying the conditions necessary for finding a component to have “hidden variable” costs and then evaluating the empirical results relative to that standard, Dr. Neels takes a circuitous path of sometimes accounting for whether or not a coefficient is significant, and sometimes ignoring it. He patches together an amalgam of “sign and significance” conditions across the constant and the weighted volume coefficients that provides an inconsistent and unsatisfactory evaluation. Finally, if he did not like the sign on the constant term, he drops it from the model even if it was statistically significant and re-estimates the model without a constant. Generally, these “pretesting” methods lead to biased and inconsistent parameter estimates.

None of this is necessary, because the conditions required for finding “hidden variable” costs in Dr. Neels’s model are straightforward. In Dr. Neels’s model variable costs, by definition, take on a value of zero when volume is equal to zero and increase as volume increases. Thus, the condition for a “hidden variable” cost in Dr. Neels’s model is that the constant is zero (reflecting the first condition) and the volume coefficient is positive and significant (reflecting the second condition). More formally, a finding of “hidden variable” costs in the model presented above, requires the following conditions: $a = 0$ and $b > 0$. For the first condition to hold, the estimated constant must not be significantly different from zero, regardless of its sign. A positive or negative constant, if it is significantly different from zero means the model fails to identify hidden variable cost. For the second condition to hold, the volume coefficient must be positive and significantly different from zero.

Of the 88 estimated regressions, this set of conditions held for only four of them. This represents a mere 4.5 percent of the regressions, which is about what one would expect from random chance when using a 95 percent level of significance. In addition, review of the four identified components reveals that they do not actually represent fixed costs. The four components with apparent "hidden variable" cost are presented in Table 7.

Table 7

Components Where the Regression Results Identified "Hidden Variable" Costs

Component Number	**Cost Segment**	**Component Description**	**FY 2014 Variability**
43	6	In-Office Direct Labor	92.89%
44	6	In-Office Support Overhead	92.89%
73	10	Equipment Maintenance Allowance	0.00%
202	18	Annuitant Health Benefits - Earned (Current)	56.23%

The first two components, numbers 43 and 44, both include very small institutional portions of city carrier in-office labor. [73] These costs reflect time associated with activities that are not related to volume, such as maintaining route books or other administrative activities. They are common to all products, and are not caused by any individual product. Component 202 was discussed in detail above, and its costs are neither fixed nor attributable to individual products.

Component 73 has a zero volume variability, so it could potentially be a fixed cost. This component contains the rural carrier equipment allowance. Although it is not a labor cost, the Equipment Maintenance Allowance (EMA) is a payment to rural carriers, to compensate them for using their own vehicle delivering mail. If there were no mail to be delivered or collected, it is unlikely that rural carriers would be required, making it highly unlikely that EMA payments would be made.

Moreover, these are costs associated with carriers driving their routes, and not associated with mail volumes. This cost structure arises not because the EMA is "fixed," but because it is a common cost—it does not change when individual product volumes change, but rather depends on non-volume factors such as distances between delivery points, and hence has a zero volume-variability:[74]

> EMA is paid when carriers use their own vehicles. Carriers receive a minimum allowance that increases on a mileage basis for routes exceeding 40 miles. Certain routes with a large number of stops in relation to the number of miles

[73] See Docket No ACR FY2014, USPS-FY14-31, FY14.ARpt.xls Component 43 institutional costs is $168.2 million as compared to total accrued costs of $2,365.8 million. Component 44 institutional costs is $37.5 million as compared to total accrued costs of $527.7 million.

[74] See, Summary Description of USPS Development of Costs by Segments and Components, FY2014 at 10-4.

> receive a supplemental allowance. Rural carriers may also be paid an incentive to buy and use right-hand drive vehicles while serving their route. Because the costs of EMA are a consequence of route mileage rather than mail volume, they are classified as institutional.

While it is likely the finding of "hidden variable" costs for these four components is spurious, review of the activities in the components, as described above, demonstrates that such a finding does not provide a basis for attributing the associated costs to products. Because of their demonstrated common nature, Dr. Neels's contention that they are "hidden variable" costs is an insufficient basis to justify attribution to individual products.

Apart from its other infirmities, Dr. Neels's analysis suffers from an erroneous application. After finding "hidden variable" costs, Dr. Neels then attempts to distribute those costs to products. When the component has a zero variability, Dr. Neels proposes attributing the costs to products on the basis of the relative shares of overall attributable costs in the previous year.[75] Dr. Neels provides no explanation of why overall attributable cost shares are a good distribution key for these specific cost components, and he fails to justify why using shares from a previous year is appropriate. Dr. Neels did not provide an analytical or causal basis for this distribution but appears to pick it as a convenient, but arbitrary, distribution key. Yet, if these components are indeed volume variable, then the distribution should be based upon the volumes that actually caused them to arise, just as it is done for all other volume variable components. Dr. Neels's shortcut approach does not do this.

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[75] See Report of Dr. Kevin Neels Concerning UPS Proposals One, Two and Three, UPS-RM2016-2/1 at 46.

In components in which the variability is positive, Dr. Neels proposes using what he calls the Postal Service's "legacy" model to distribute the costs.[76] Presumably this is the distribution key already used for the volume variable portion of the component. In other words, in components like Component 43, Dr. Neels would increase the variability by adding institutional costs to attributable costs. In many cases, Dr. Neels would essentially convert the existing variability to 100 percent -- and distribute all of the accrued costs to products. Again, he provides no justification why his rudimentary equation should override detailed variability analyses that have been reviewed and approved by the Commission.

Finally, in constructing his distribution mechanism, Dr. Neels has ignored the fact that his estimated equations actually provide purported variabilities for the "hidden variable" costs and ignores those variabilities when distributing institutional costs to products. It would be more appropriate for him to us the estimated variabilities from his equations when attributing the costs to products. However, reviewing the variabilities implied by his models (in cases in which the weighted volume coefficient was positive and significant) shows that they regularly provide apparently nonsensical variabilities. For example, the implied variability for component 43, Institutional In-Office Labor is *327.4* percent, meaning these so-called "hidden variable" costs increase or decrease at a rate of 3 times the percentage volume change. Such extreme variabilities again demonstrate the infirmity of Dr. Neels's proposed model.

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[76] Id. at 47.

Table 8

Variabilities Associated With the First Ten of Dr. Neels's Equations

Component Number	**Variability**
2	0%
9	229.3%
13	224.2%
17	119.4%
18	103.6%
33	132.4%
41	260.9%
43	327.4%
44	316.9%
53	38.7%

APPENDIX

Demonstrating that Dr. Neels's Fully Distributed Costs Do Not Equal Shapley Costs with a Constant Elasticity Cost Function and Three Products

Let the cost function for cost component j be:

$$C_j = \alpha D_j{}^{\beta},$$

where, α>0 is a parameter, β>0 is the cost elasticity, and D_j is the cost driver. Note that all of the component costs are variable costs in that total component cost is zero if volume is zero. Each of the three products, indexed by the letter "i", requires D_i units of the cost driver:

$$D_j = \sum_{i=1}^{3} D_{ij},$$

and the distribution key share of product i in the cost driver is

$$d_{ij} = \frac{D_{ij}}{D_j}, \qquad i = A, B, C$$

Note that the marginal cost function (with respect to the driver) is nonlinear if 0< β <1:

$$MC_j = \frac{\partial C_j}{\partial D_j} = \alpha\beta D_j{}^{\beta-1}.$$

Total component volume variable cost is the product of the marginal cost of the D^{th} unit and the total amount of the driver:

$$VVC_j = \beta\alpha D_j{}^{\beta} = \beta C_j\,.$$

The volume variable cost of product i is

$$VVC_{ij} = d_{ij}\alpha\beta D_j = d_{ij}\beta C_j.$$

Dr. Neels proposes to distribute the entirety of the variable (marginal and inframarginal) costs of the component in proportion to the cost driver shares:

$$C_i^{Neels} = d_{ij}C_j = d_{ij}\alpha D_j{}^{\beta} = D_{ij}\alpha D_j{}^{\beta-1}.$$

Note that this quantity depends only on the product's amount of the cost driver D_{ij}, and the total amount of the cost driver.

Computing the Shapley costs for each product requires computing the additional costs for the products in each possible ordering, and averaging the results. With three products, there are six possible orderings: ABC, ACB, BCA, CAB, BCA, and CBA. In ordering ABC, the additional cost of Product A is evaluated as if Product A constituted the first D_{Aj} units of the cost driver, the additional cost of Product B is evaluated as if Product B constituted the next D_{Bj} units of the cost driver, and the adidtional cost of Product C is evaluated as if Product C constituted the last D_{Cj} units of the cost driver.

Given the six orderings, to calculate the Shapley costs, it is necessary to compute four distinct costs for each product: its true incremental cost IC_{ij} (when it is the last D_{ij} units), which appears twice in the Shapley cost expression; its stand-alone cost SAC_{ij} (when it is the first D_{ij} units), which also appears twice; and the additional costs when it is the middle D_{ij} units following each of the other products, IC_{ikj}, for $k \neq i$. For Product A:

$$IC_{Aj} = \alpha\left(D_j{}^{\beta} - \left(D_j - D_{Aj}\right)^{\beta}\right).$$

$$SAC_{Aj} = \alpha D_{Aj}{}^{\beta}.$$

$$IC_{ABj} = \alpha((D_{Aj} + D_{Bj})^{\beta} - D_{Bj}{}^{\beta})$$

$$IC_{ACj} = \alpha((D_{Aj} + D_{Cj})^{\beta} - D_{Cj}{}^{\beta})$$

The Shapley cost for Product A is:

$$SC_{Aj} = \frac{(2 \cdot IC_{Aj} + 2 \cdot SAC_{Aj} + IC_{ABj} + IC_{ACj})}{6}.$$

Or,

$$SC_{Aj} = \frac{2\alpha\left(D_j{}^{\beta} - \left(D_j - D_{Aj}\right)^{\beta}\right)}{6} + \frac{2\alpha D_{Aj}{}^{\beta}}{6} + \frac{+\ \alpha\left(\left(D_{Aj} + D_{Bj}\right)^{\beta} - D_{Bj}{}^{\beta}\right)}{6} + \frac{\alpha((D_{Aj} + D_{Cj})^{\beta} - D_{Cj}{}^{\beta})}{6}.$$

This result shows that the true Shapley cost is very different from Dr. Neels's FDC method, as it depends on the values for D_{Aj}, D_{Bj}, and D_{Cj} separately. Dr. Neels's proposed shortcut does not equal and is not "fully consistent" with Shapley costs.

There are two special cases where Dr. Neels's method does produce the Shapley cost. First, if each product has an equal distribution key share, such that $D_{Aj} = D_{Bj} = D_{Cj} = D_j / 3$, then both Dr. Neels's cost and the Shapley cost are both simply one-third of the total cost, C/3. In practice, this is not applicable, as all, or virtually all, cost components have distribution keys with unequal shares across products. Second, if the cost component has a unit elasticity (i.e., 100 percent volume-variability), then Dr. Neels's method and the Shapley method produce the same costs for each product.

However, if the component variability was 100 percent then volume variable cost equals accrued cost, so all of the component cost has already been attributed to individual products.