OFFICE OF INSPECTOR GENERAL
UNITED STATES POSTAL SERVICE

Examining Changes in Postal Product Costs

RARC Report

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Introduction

Over the past 10 years, the U.S. Postal Service has experienced both sharp declines in overall mail volume and substantial changes in the volumes and proportions of the different types of mail deposited in its system.[1] In response, Postal Service management has cut overall costs using a variety of strategies, including rationalizing its network, hiring lower-priced labor, and, in some cases — such as local First-Class Mail delivery — lowering service standards.[2] How have changes in the overall business environment and Postal Service operations affected specific postal product costs?

The U.S. Postal Service Office of Inspector General (OIG) worked with Professor Michael Bradley, an expert in postal costing and economics, to examine and analyze product costs and cost changes from fiscal year (FY) 2006 to FY 2015. In order to make the comparison meaningful, we first mapped postal products and sub-products from FY 2015 to the FY 2006 definitions. We then applied mathematical tools to data from the Postal Service's Cost and Revenue Analysis (CRA) report to estimate changes in unit cost by source. Details of this analysis are in the attached technical report.

The report quantifies the main drivers behind cost changes for the Postal Service's four main traditional products: First-Class Mail, Standard Mail, Periodicals, and Package Services.[3] It includes four key external factors that have driven cost changes from 2006 to 2015: inflation, product mix, individual volume change, and overall volume change. With these external factors accounted for, we attribute the remaining change in unit cost to other factors associated with management activity, such as productivity improvements, service modifications, and wage reductions.[4] Such factors are at least partially within the Postal Service's control. This is especially important to note because this analysis finds that via such factors, the Postal Service was able to reduce the costs of all products but one, Periodicals. These cost reductions occurred despite a growth in delivery points.

Another important relationship highlighted by this work is the impact of the volume change of one product on the costs of other products. This occurs because products share the costs of the network, including transportation, processing facilities, and delivery activities. Any decline in overall mail volume results in fewer pieces of mail sharing the costs of the network. While this theoretical concept has been understood and accepted generally, its impact on Postal Service products has not been quantified until now.

The OIG finds the following observations from this report particularly noteworthy.

First-Class Mail

OIG Observations

- First-Class Mail's unit cost rose by 2.5 cents (13 percent) between 2006 and 2015.
- The upward pressure for this increase came from two main sources — inflation and the sharp reduction in the volume for First-Class Mail.
- When adjusted for inflation, changes in volume, and mail mix, the Postal Service was able to bring *down* First-Class Mail unit cost by a full penny over the period studied. This was accomplished primarily through lowering costs due to other factors, including average wages, service reductions, and improvements in efficiency (e.g. plant consolidations, reductions in workhours, expansion in self-service kiosks, etc.).

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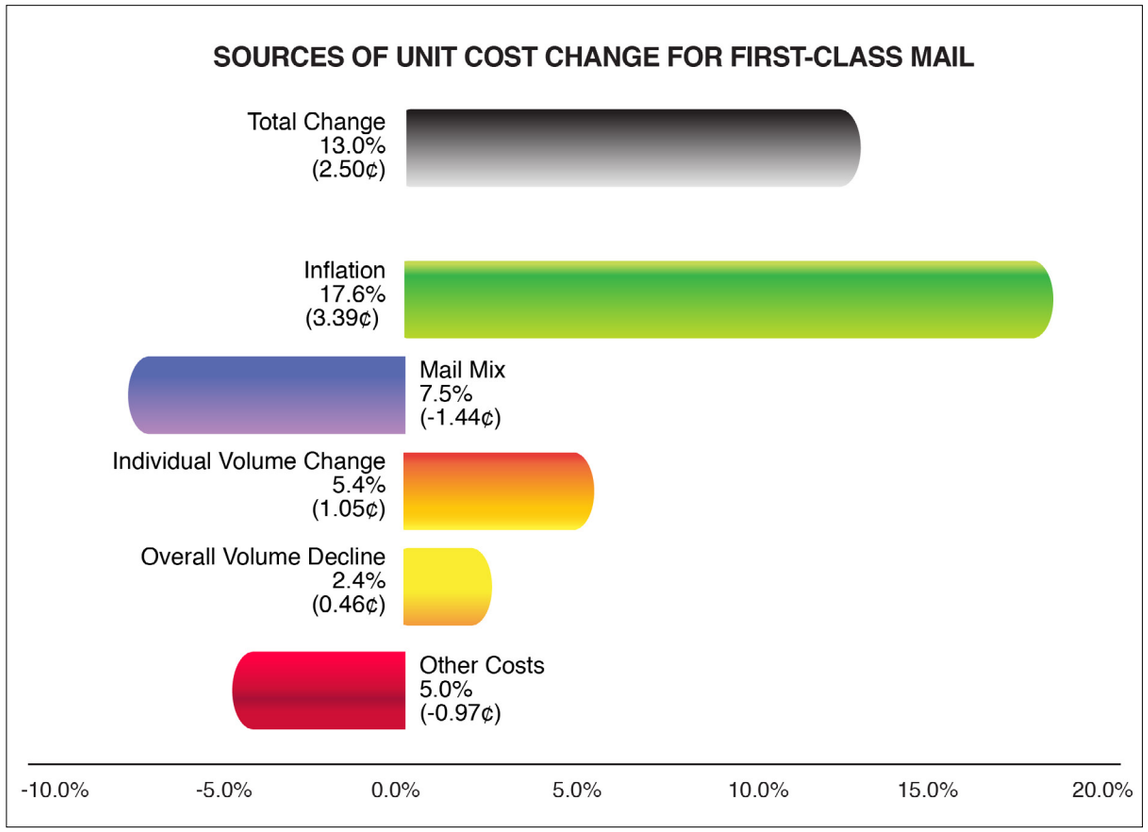
1 See for example: https://about.usps.com/who-we-are/postal-facts/decade-of-facts-and-figures.htm.
2 See for example: U.S. Postal Service, "USPS Delivery Standards and Statistics Fact Sheet," March 2015, https://about.usps.com/news/electronic-press-kits/our-future-network/assets/pdf/ofn-usps-dss-fact-sheet.pdf.
3 The terms "product" and "sub-product" used in this analysis encompass the technical terms: mail classes, subclasses, products, and rate categories.
4 In the attached technical report, costs associated with other factors are called "productions costs."

- One of the foremost things the analysis reveals is that the 35.1 percent fall in First-Class Mail volume resulted in a 1.05 cent increase in cost per piece in the last 9 years. This quantification illuminates the important connections between individual product volume level and unit cost.

- The analysis quantified an equally important relationship between mail mix and unit costs. The increase in First-Class Presort Mail lowered unit cost by a penny and a half, or 7.5 percent. This type of cost saving is accompanied by reduced revenue, so it is crucial for the Postal Service to set discounts carefully to help assure that forecasted cost savings are realized in order to achieve a net benefit.

- It is generally understood that when resources are shared, the cost of adding volume of one product depends upon the volumes of other products. This analysis has quantified this important relationship between the overall mail volume decline and unit cost: a fall of 28 percent in the overall volume of mail led to a 2.4 percent increase in First-Class Mail's unit cost over the 2006 to 2015 time-period.



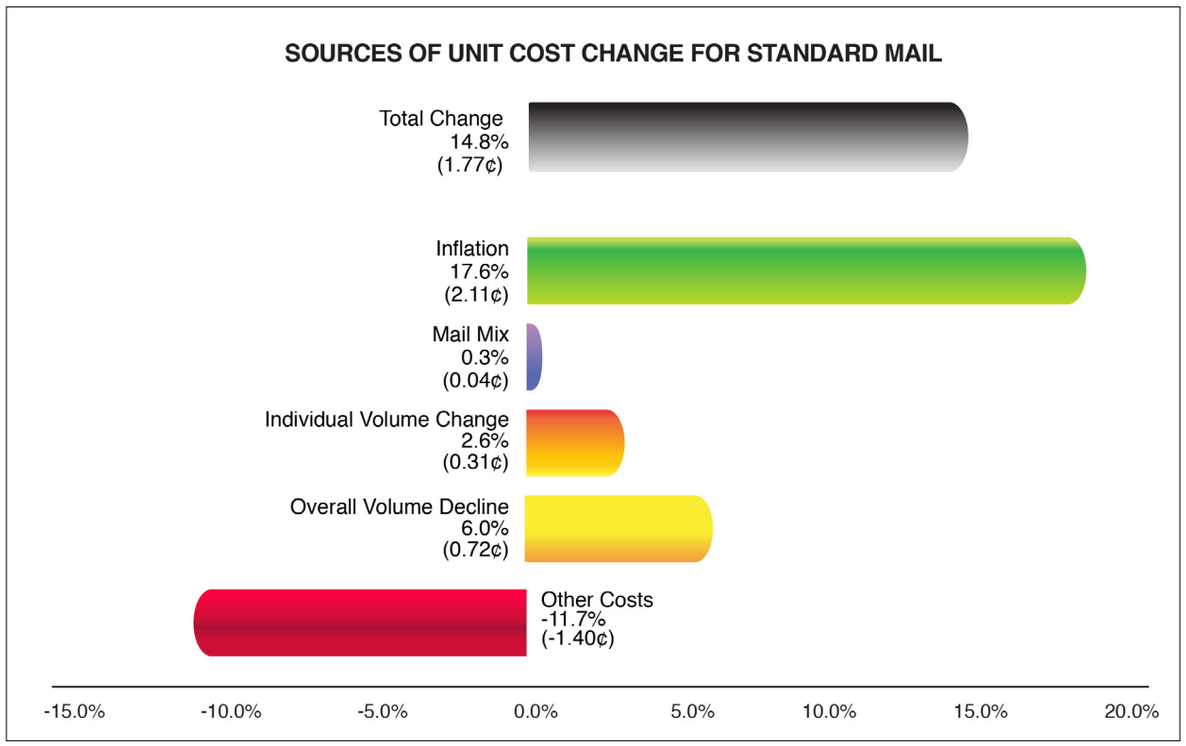
Source: CRA and Professor Michael Bradley.

Figure contains rounding.

Standard Mail

OIG Observations

- Standard Mail's unit cost rose by 1.77 cents (14.8 percent) between 2006 and 2015.
- The upward pressure for this increase came from two main sources — inflation and the reduction in the overall volume of mail.
- The study reveals that the one source of downward pressure was other factors. Changes in service standards, tightening of mailing standards, technology improvements, and lower average wages lowered Standard Mail's unit cost almost 12 percent or 1.4 cents. This category also includes the impact of the Standard Mail load leveling initiative, which was introduced in April 2014.
- Furthermore, an increase in drop-shipped Standard Mail volume to the Destination Delivery Unit (DDU) drove down overall unit cost.
- Standard Mail was not subject to an appreciable product mix effect; the mail mix of its sub-products was relatively constant over the 2006 to 2015 time-period.



Source: CRA and Professor Michael Bradley.

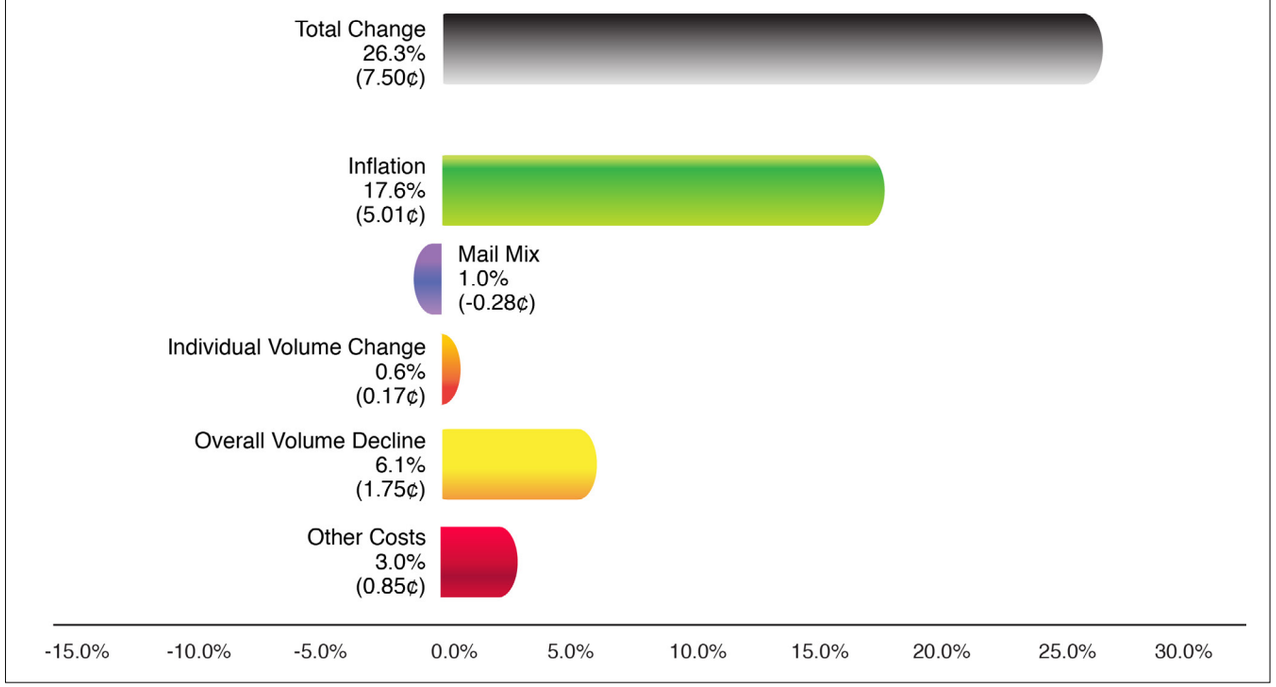
Figure contains rounding.

Periodicals

OIG Observations

- Periodicals Mail's unit cost rose by 7.5 cents (26.3 percent) between 2006 and 2015.
- Similar to Standard Mail, the upward pressure for this increase came from two main sources — inflation and the reduction in the overall volume of mail.
- After removing the impact of inflation, Periodicals is the only product that still experienced an increase in unit cost.
- But, because Periodicals Mail is a smaller volume product, the analysis shows that the decline in overall volume had a bigger impact on its unit cost. We show that the unit cost for Periodicals rose 1.75 cents as volume fell by 28 percent. The same decline in volume increased the unit cost of Standard Mail by only 0.72 cents and First-Class Mail by 0.46 cents.
- The two factors contributing to Periodicals cost changes are primarily not controllable; thus, moving toward 100 percent cost coverage will likely continue to be challenging without steep price increases.
- The study reveals that unlike the other products where things like changes in other factors — including service, technology, and lower average wages — led to lower unit costs, in Periodicals, other factors led to a 0.85 cent or 3 percent increase in cost.
- This may imply that some changes in technology that helped decrease the unit cost of other products did not benefit Periodicals, which suggests a need for further examination by the Postal Service. While the high unit cost increases for Periodicals could be due at least in part to a high percentage of manual handling, there may be other technology and productivity factors to consider.

SOURCES OF UNIT COST CHANGE FOR PERIODICALS



Source: CRA and Professor Michael Bradley.

Figure contains rounding.

Package Services

OIG Observations

- Package Services' unit cost declined by [redacted] between 2006 and 2015.
- The main source of downward pressure was from the change in mail mix, as more parcels were dropped at the delivery unit (and returns picked up at the delivery unit). In fact, isolating the impact of the change in product mix alone has the result of lowering unit cost by [redacted]
- The second largest driver behind the reduction in cost is other factors — including service, technology, and lower average wages — which reduced unit cost by [redacted]. This could at least be partially driven by the use of lower-wage labor and increased efficiency from transitioning Bulk Mail Centers to Network Distribution Centers.
- While the increase of parcel volume had a negative impact on unit cost, it was not large — a decline of [redacted][5]
- More interesting is the impact of overall volume, as it shows that the decline in letters has led to an increase in the unit cost of parcels. Isolating this impact results in a unit cost increase of [redacted]). This may mean that to remain competitive in package delivery, under its current strategy, the Postal Service needs to retain as much of its non-package volumes as possible.

[redacted]

Source: [redacted].

5 The decline in unit cost may have been limited because, in some instances, the Postal Service has recently used parcel-only delivery runs to handle the additional parcel volume. As an example, the agreement between the Postal Service and Amazon to deliver parcels on Sunday started in October 2013. U.S. Postal Service Office of Inspector General, *Sunday Parcel Delivery Service,* Report Number DR-AR-15-002, December 5, 2014, https://www.uspsoig.gov/sites/default/files/document-library-files/2015/dr-ar-15-002.pdf.

Considerations for the Future

The quantification of unit cost changes identified in this work highlights a number of important findings and raises questions for the Postal Service and its stakeholders to consider. We found that the Postal Service was able to reduce the unit cost of all products but one, Periodicals, through technology and productivity improvements, service modifications, and lower average wages. These cost reductions occurred despite a growth in delivery points. The question for the Postal Service then becomes, can Periodicals' processing costs be further lowered through use of additional technology and other changes?

Further, the quantification highlights the impact of the volume change of one product on the costs of other products. Could consideration of this finding assist in evaluating strategic efforts to increase volumes, such as Negotiated Service Agreements (NSAs)? That is to say, should the financial impact of additional volumes and change in product mix on other products — outside of the one(s) directly negotiated in the NSA — be considered?

The Postal Service has been successful in absorbing a near doubling in Package Services volume without dramatic unit cost increases. If package volume continues to grow, can additional volume be integrated into the postal network in a way that maintains or continues to reduce package services unit cost?

It may be that further analysis of past cost saving initiatives, such as network rationalization and Standard Mail load leveling, would help management determine the likely success of cost-savings initiatives going forward.

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Measuring the Sources of Change in the Postal Service's Product Costs

Technical Report

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A. Introduction

The U.S. Postal Service (Postal Service) is facing a challenging economic environment, highlighted by substantial declines in demand for its major mail products.[1] As a network firm subject to a price cap on those products, volume declines force it to face a number of difficult issues, including changes in product costs. Understanding the sources of these product cost changes may help provide insight into what the Postal Service can do to adjust to these new realities. In this report, we develop methodologies for measuring the sources of change in the Postal Service's product costs, capturing the essential elements of the economic environment in which the Postal Service operates, while being consistent with the Postal Service's product cost structure.

The next section introduces and explains the product cost measures that are appropriate for the Postal Service. This is followed by a brief description of each of the four main sources of change in product costs and a detailed presentation of the methodology for measuring the cost changes caused by each source. We then apply these methodologies to the actual changes in product costs for First-Class Mail, Standard Mail, Periodicals, and Package Services, from 2006 to 2015.[2]

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1 In this report, the terms "product' and "sub-product" will be used in a generic sense. Prior to the passage of the Postal Accountability and Enhancement Act (PAEA), the Postal Service used the term "Classes" for its products and "Subclasses" for its sub-products. After the PAEA's passage, the Postal Service used the terms "Products" and "Rate Categories." Because our analysis bridges the passage of the PAEA, we will avoid this confusing jargon and simply refer to products and sub-products in all time periods.

2 The years referred to in this report are Postal Service fiscal years.

B. Product Costs

The Postal Service is a multiproduct firm with common production, in which two or more outputs share at least one input in the production process. As a result, the Postal Service's economic structure differs from the textbook case of a single-product firm.

This difference in economic structure implies important differences in the way costs are generated. 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. 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. Second, multiproduct firms are characterized by the existence of the economies of scope. Economies of 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.

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 that 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.

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 do not provide meaningful measures of the cost behavior in the multiproduct firm. This is because a useful construction of average costs is not possible, because there is no way to construct a meaningful single measure of output to serve as the denominator. Thus, these traditional product cost measures have no meaning in a multiproduct firm.

Instead, in a multi-product firm like the Postal Service, product costs are measured with marginal costs, or, in the parlance of the Postal Service product costing system, "volume variable costs per piece."[3] We thus examine changes in marginal cost for the Postal Service's four main products: First-Class Mail (First Class), Standard Mail (Standard), Periodicals, and Package Services. We compare the FY 2015 marginal costs with the FY 2006 marginal costs and investigate the sources of those changes in marginal costs.

C. Sources of Change in Product Costs

The Postal Service's product costs changed substantially from 2006 to 2015, reflecting the many changes in the postal environment. For example, the marginal cost for Standard Mail increased by 14.8 percent, while the marginal cost of Package Services fell by [redacted].

3 U.S. Postal Service, Public Cost and Revenue Analysis, Fiscal Year 2015, p.1.

There are four main sources of change in Postal Service product costs: (1) general price level; (2) workload arising from changes in product mix; (3) individual product and overall volumes; and (4) production cost levels.[4] Each of those sources is briefly introduced in this section, and the following sections discuss the methodologies for measuring the changes in marginal cost that were caused by these different sources. Note that some sources of change may increase marginal costs, while other sources of change may decrease those costs, leading to potentially offsetting effects.

C.1 Changes in the General Price Level

A widely misunderstood economic concept is inflation. In the popular press, inflation is often used to relate to the percentage change in a single good's price or a group of goods' prices. It is not unusual to hear references to terms like "house-price inflation" or "college tuition inflation." Changes in the price of one good, or in the price for one group of goods, is actually a change in relative prices, not inflation. Instead, inflation is the common increase in all prices in the economy; it is "an increase in the overall level of prices in the economy."[5] The important point is that inflation incorporates increases in all prices, including input prices, in the economy:[6]

> Inflation just adds an equal amount to the growth rate of all prices and wages and to the nominal interest rate on all assets; it therefore has no effect on relative prices, real wages, or real interest rates.

4 Marginal costs could also change due to changes in the methodology used to calculate those costs. The two major changes in methodology over this period were a new purchased highway transportation study and a new city carrier street time study. Neither study has a major impact on the overall marginal costs.

5 Mankiw, N. Gregory, Principles of Macroeconomics, 3rd Edition, Thomson South-Western, Mason, OH, 2004, p. 12.

6 Romer, David, Advanced Macroeconomics, 2nd edition, McGraw-Hill, New York, 2001, p. 519.

Inflation arises from increases in aggregate demand – the overall demand for all goods and services in the economy. Relative price increases, in contrast, come about because of changes in demand for an individual good or group of goods. Suppose that there was no increase in aggregate demand, but the demand for houses increased. Then, only the prices of houses would increase, not the prices of all goods. In this example, the relative prices of houses increased, because house prices rose by 2 percent and no other prices increased.

Relative price increases can also occur in an inflationary economy. They will occur if the price of a good or service rises faster than inflation – which is the common increase in all prices. If inflation is 2 percent, but the price of houses rises by 4 percent, then there is again an increase in the relative price of houses. Note that in this example house prices went up for two reasons: a 2 percent increase reflecting aggregate demand increases, and another 2 percent increase reflecting an increase in demand for houses relative to other products. Because an observed price or cost can rise for both reasons, to see if a price or cost is increasing faster or slower than inflation, one must compare the percentage increase in the price or cost with inflation, which is the percentage increase in the aggregate "price level."[7]

> The price level measures average prices of goods and services in the economy. The inflation rate is the percentage increase in the price level from one year to the next.

Accurately measuring inflation is a challenge because observed price increases are the result of both relative price changes and inflation. A number of different

7 Hubbard, R. Glenn, and O'Brien, Anthony Patrick, Macroeconomics, 5th edition, Pearson, New York, 2015, p 279.

approaches have been proposed but all have their shortcomings.[8] Even imperfectly measured, inflation is an important guidepost for comparing values through time. To accurately compare a marginal cost from 2006 with a marginal cost from 2015, it is important to adjust the comparison for general inflation to see if the marginal cost is rising or falling relative to other prices and costs in the economy.

For example, if a firm's costs were rising by 3 percent and the inflation rate were 2 percent, then it is fair to conclude the firm's costs would be rising due to factors other than inflation. On the other hand, if a firm's costs are rising at a rate below inflation, it is offsetting the inflation effect on cost with some other cost savings, improving its relative cost position.

C.2 Changes in Workload Arising from Changes in Product Mix

The Postal Service's products, such as First-Class Mail or Package Services, are made up of a number of sub-products. These sub-products vary in the amount of work the Postal Service must complete to provide the required service. For example, some sub-products may require mail processing, transportation, and delivery, whereas others may simply require delivery.

If the Postal Service's products are not homogenous through time, then its products' marginal costs can change because of variations in the amounts of sub-products that make up the product. These variations alter the workload of the "average" unit of the product and thus affect its marginal cost. The marginal cost for First-Class Mail, for example, is a volume-weighted average of the marginal costs for the

8 For a discussion of issues in measuring inflation in actual economies and the impact of price changes that occur for reasons other than inflation, see, Bradley, Michael D., Jansen, Dennis W., and Sinclair, Tara M., "How Well Does 'Core' Inflation Capture Permanent Price Changes," Macroeconomic Dynamics, Vol. 19, 2015, pp. 791-815.

sub-products within First Class, and those sub-products have different amounts of work associated with them. First Class Single-Piece mail has a higher work content than First Class Presort mail, so a shift away from single-piece to presorted mail would reduce the average work content of First Class. Such a shift would also reduce First- Class Mail's marginal cost. Not accounting for this change in product mix would lead to misleading inferences about the nature of changes in First-Class Mail's marginal cost. We thus will control for changes in workload as caused by changes in product mix.

C.3 Changes in Individual Product and Overall Volume

One of the primary characteristics of a network industry is the presence of economies of scale and density. These economies create a situation in which the marginal cost of output is inversely related to the level of output. Network economies generate the outcome that as output rises, the additional cost for additional units of output falls. However, if output should fall, the economies of scale effect works in reverse. As output falls, marginal cost rises. This can cause a difficult situation for a network industry, in which marginal costs are rising at the very time the industry is trying to minimize costs due to declining revenue.

In addition to individual economies of scale, Postal Service products are generally produced in combination with one another using shared resources. However, when resources are shared, the cost of adding volume of one product depends upon the volumes of all other products. For example, higher volumes reduce the unit transportation costs for all products being transported, so a specific product will have a lower marginal cost when the volumes of all other products are high. The marginal cost of any one product will depend upon the volumes of the other products, as well as its

own. In this way, products' marginal costs are dependent upon both their own volumes and the level of overall volume of the Postal Service.

C.4 Changes in Production Cost Levels

As discussed above, a firm's marginal costs can change for a variety of reasons and to this point we have accounted for most, but not all, of those reasons. The remaining set of possible sources of changes will be called production cost level changes. This name is chosen because these factors cause changes in a product's marginal cost at all amounts of output, and can thus be considered a change in the "level" of production cost. Examples of changes in a firm's production cost level include changes in productivity, changes in technology, changes in service standards, changes in product quality, and changes in input prices for reasons other than inflation.

Given the multitude of factors and the difficulty in sorting out the quantitative effects of some of these factors, quantification of the individual effects is beyond the scope of this paper. We thus calculate a single value for changes in production cost levels by subtracting the explained changes in marginal cost from the overall change in marginal cost. Further investigation of reasons behind these cost changes is an important topic for future research.

D. Methodology for Measuring Marginal Cost Changes Due to Changes in the General Price Level

As discussed above, product costs can change due to general inflation — the persistent rise in all prices across the economy. Accurate comparison of product costs through time requires accounting for the changes in product costs due to inflation. Note

that this is different from measuring product cost changes that occur in the firm's own input prices because of changes apart from inflation. While input prices change, in part, due to inflation, they also change for a variety of other reasons. Input price changes not caused by inflation are relative price changes, and should be analyzed separately. For example, if inflation is 2 percent, but a firm's wages rise by 3 percent, then the part of the wage increase that is greater than inflation is a change in the firm's production cost level. In contrast, if the Postal Service negotiated wage increases that were less than the rate of inflation, then this effect would show up as reduction in the production cost level.

Consequently, the appropriate method for accounting for changes in the general price level on product cost is through the use of a broad measure of inflation:[9]

> You are likely to receive a much higher salary after graduation than your parents did 25 or more years ago, but prices 25 years ago were, on average, much lower than prices today. Put another way, the purchasing power of a dollar was much higher 25 years ago because the prices of most goods and services were much lower. Price indices such as the CPI give us a way of adjusting for the effects of inflation so we can compare dollar values from different years.

However, all measures of inflation have their weaknesses. While in concept, inflation is the common increase in all prices, in practice, inflation is measured by calculating an average of actual price increases. This calculation can include relative price changes. Although a number of different price indices were considered for this analysis, we will apply the most widely used measure, the Consumer Price Index

9 Hubbard, R. Glenn, and O'Brien, Anthony Patrick, Macroeconomics, 5th edition, Pearson, New York, 2015, p 282.

(CPI).[10] We do so because the CPI is the best known, most widely employed inflation measure. It is used, for example, to adjust Social Security payments, income tax brackets, and the Postal Service's price cap. Fortunately, over the time period of our analysis, the results are not impacted by the choice of inflation measure.[11]

The formula for adjusting the actual FY 2015 marginal costs for inflation is:

$$Inflation\ Adjusted\ MC_{2015} = \ MC_{2015} * \frac{CPI_{2006}}{CPI_{2015}}.$$

This formula removes the effect of inflation from the FY 2015 marginal costs. If the only reason marginal cost increased between FY 2006 and FY 2015 was because of inflation, then the inflation-adjusted FY 2015 marginal cost would exactly equal the FY 2006 marginal cost.

E. Methodology for Measuring Marginal Cost Changes Due to Changes in Workload Arising from Changes in Product Mix

As explained above, if a product is not homogenous through time, then its marginal cost can change because of changes in its "average" workload. We thus will control for changes in workload as caused by changes in product mix. We can calculate the effect of a workload change on marginal cost by calculating what the marginal cost would have been without a change in workload. If we keep the product mix the same across the two years for which we are comparing marginal costs, we can

10 Specifically, we use the Consumer Price Index for All Urban Consumers: All Items.
11 We examined and compared the impacts of inflation on Postal Service marginal costs as measured by three indices: the Consumer Price Index, the Producer Price Index, and the Gross Domestic Product Deflator. The results were within a few tenths of one cent of each other. Despite variations on a month-to-month basis, the three measures of inflation tracked each other closely over the 2006 to 2015 period, resulting in little variation in inflation adjusted marginal costs.

conclude that any remaining changes in marginal cost are not from a change in workload.[12]

The most logical approach for controlling for product mix is through the use of a marginal cost index. To see this, first consider, conceptually, how we would account for volume mix changes. In any given year, a product's marginal cost is the volume-weighted average of the marginal costs of its sub-products. Over time, the volume weights can change, making it difficult to measure the true change in the product's marginal cost. To keep the focus on that key measurement, we keep the volume weights constant and then compare marginal costs over time. In this way, we can be sure that all changes in the products' marginal costs arise from changes in the sub-products' marginal costs and not from changes in the mix of sub-products and thus product workload. In other words, when we compare marginal costs from two years, we can be sure both contain the same amount of workload.[13]

In a "base year," like the first year of our analysis, a product's overall marginal cost, (MC_b), is the volume weighted (v_i^b) sum of its sub-products' marginal costs, (MC_i^b):

$$MC_b = \sum_{i=1}^{m} MC_i^b v_i^b.$$

12 Our analysis is focused on variations across sub-products as defined by the Postal Service. However, there can be workload changes even within a sub-product if the average weight or distance traveled by the sub-product changes. A more detailed analysis incorporating these changes within sub-product is beyond the scope of this paper but is an interesting topic for further research.

13 For example, if a product has one sub-product that does not require any sorting because the mailer delivers it directly to the destination post office, then its workload would be less than an alternative sub-product that requires sorting by the Postal Service. If this product experienced a shift from the high workload sub-product to the low workload sub-product, then its marginal cost will decline because its average workload has fallen.

But we could also calculate the workload-adjusted, current year product marginal costs, (MC_C^*), by using the base year volume weights (v_i^b) along with the current year sub-product marginal costs (MC_i^c):

$$MC_C^* = \sum_{i=1}^{m} MC_i^c v_i^b.$$

Comparing these two marginal costs identifies the change in product costs that arise apart from the effect of any volume changes. Yet, such a comparison is exactly what a Laspeyres Index does, as shown by the following formula:

$$MCI_L = 100 * \frac{\sum_{i=1}^{m} MC_i^c v_i^b}{\sum_{i=1}^{m} MC_i^b v_i^b}.$$

Applying the index number approach raises an important implementation question: which year's volume weights should be used for making the comparison through time? In our specific case, the question is whether we should use FY 2006 or FY 2015 volumes to calculate the workload adjusted marginal costs. Both approaches have their disadvantages.

A Laspeyres index reveals what marginal cost would be generated in the current year by the mix of volumes provided in the base year. It measures the change in marginal cost associated with the base year volumes. As a result, the Laspeyres index suffers from positive bias, meaning that it does not account for the fact that postal customers are likely to consume less of those postal services whose marginal cost has risen relative to the other provided services. It thus does not reflect the current product mix and tends to overstate the true change in marginal cost.

The potential overstatement problem is addressed by the Paasche index, which takes the current year volumes as its weights and calculates the change in marginal cost associated with current year volumes:

$$MCI_P = 100 * \frac{\sum_{i=1}^{m} MC_i^c v_i^c}{\sum_{i=1}^{m} MC_i^b v_i^c}.$$

The Paasche index solves the positive bias problem, but it suffers from negative bias. In other words, it puts too much weight on those postal services whose marginal cost has fallen sharply relative to the others, and tends to understate the true change in marginal cost. Because we are investigating a situation in which some marginal costs have risen while some marginal costs have fallen, both of the potential biases are a concern.

To solve both of these problems simultaneously, one needs to apply a so-called “superlative” price index. One such index is the Fisher Ideal index, which is the geometric average of the Laspeyres and Paasche indices:

$$MCI_F = \sqrt{\frac{\sum_{i=1}^{m} MC_i^c v_i^b}{\sum_{i=1}^{m} MC_i^b v_i^b} * \frac{\sum_{i=1}^{m} MC_i^c v_i^c}{\sum_{i=1}^{m} MC_i^b v_i^c}}.$$

The value for the Fisher Ideal index will always be in between the values for the Paasche and Laspeyres indices. In this way it mitigates either positive or negative bias. We will apply the Fisher Ideal index to measuring the change in marginal cost adjusted for volume mix, as explained below.

Before the index number approach can be applied, one additional issue must be addressed. To compare a product’s marginal costs through time, its sub-products must

be comparable across the years. Otherwise the product's marginal cost could have changed because the product's mix of sub-products changed.

The general structure of the Postal Service's four main products remained roughly the same between FY 2006 and FY 2015, but for certain products, the Postal Service revised its sub-product offerings. In FY 2015, the Postal Service offered a more disaggregated product offering, and some products were split between market dominant offerings and competitive offerings. To accommodate these various changes, we must map the FY 2015 product structure back to the FY 2006 product structure.

At first blush this may seem difficult, because at the level of sub-products there appear to be material differences across the two years. However, this turns out to be more a result of presentation than of actual mismatch. The Postal Service provides the costs, volumes, and revenues for its products and sub-products in its annual Cost and Revenue Analysis Report (CRA). However, the Postal Service actually records its volumes at a more detailed level, and produces the detailed measures in a set of reports called the "billing determinants."[14] The detail in the billing determinants reports allows us to directly link FY 2015 sub-products back to their FY 2006 counterparts, and then re-arrange those sub-products into the FY 2006 product structure. This allows direct comparison of FY 2006 product costs and FY 2015 product costs. Because this sub-product mapping issue varies by product, we will look separately at the requisite mapping for First-Class Mail, Standard Mail, Periodicals, and Package Services.

E.1 Mapping First-Class Mail

In FY 2006, First-Class Mail had four categories:

14 Billing determinants are filed with the Postal Regulatory Commission by the Postal Service for each class of mail. These reports contain volumes and revenues for each rate category.

- Single-Piece Letters
- Presort Letters
- Single-Piece Cards
- Presort Cards

Note that despite the titles, both single-piece and presort “letters” included First Class Flats and First Class Parcels. By FY 2015, First-Class Mail’s structure was more disaggregated, primarily with flats, parcels, and letters broken out separately. In addition, Negotiated Service Agreement (NSA) mail was shown separately and two international categories were included.[15] Finally, First Class Package Services was a competitive product offering, and was no longer within the First Class market dominant product group. Specifically, First-Class Mail had the following structure in FY 2015:

- Single-Piece Letters
- Single-Piece Postcards
- Presort Letters
- Presort Cards
- Flats
- Parcels
- First Class Package Services (Competitive)

To achieve a consistent product definition across the two years, FY 2015 First Class Flats and First Class Parcels must be assigned to one of the FY 2006 letter categories. This can be done with the Postal Service’s billing determinants, which break out First Class Flats into their single-piece and presort categories. Applying the billing determinants provides the following breakout of FY 2015 First Class Flats:

15 The international products are excluded from the analysis because they were not in First-Class Mail in FY 2006. Also in the FY 2015 CRA, the First Class Negotiated Service Agreement (NSA) volumes were zero. Thus, NSAs are not included in the formulas.

FY 2015 First Class Flats Breakout	
Single Piece	63.4%
Presort	36.6%

In terms of parcels, review of the billing determinants shows that all First Class Parcels are single-piece, retail pieces, so they will be assigned to the single-piece category. First Class Package Services can be assigned to the single-piece and presort categories based upon its own billing determinants. The FY 2015 billing determinants for First Class Package Services show that [redacted] percent are presorted, and the remaining [redacted] percent are single piece. The FY 2015 volumes will be assigned to the presort and single-piece categories on that basis. In sum, the recombination of FY 2015 categories into consistent FY 2006 groupings is presented in Table 1. It is this structure that will be used to calculate the overall marginal cost for First-Class Mail in FY 2015.

Table 1
First-Class Mail Mapping

FY 2006 Categories	FY 2015 Categories
Single-Piece Letters	Single-Piece Letters Single-Piece Flats First Class Parcels Single-Piece First Class Package Services
Presort Letters	Presort Letters Presort Flats Presort First Class Package Services
Single-Piece Cards	Single-Piece Cards
Presort Cards	Presort Cards

E.2 Mapping Standard Mail

In FY 2006, the structure of Standard Mail was very simple; it was broken into two categories, Enhanced Carrier Route (ECR) and Regular. By FY 2015, there were many more distinctions among Standard Mail categories. Eight different categories were included in the product:

- High Density and Saturation Letters
- High Density and Saturation Flats and Parcels
- Carrier Route
- Letters
- Flats
- Parcels
- Standard Mail NSAs
- Every Door Direct Mail Retail

Comparison across years requires combining the eight FY 2015 categories into the two categories from FY 2006. In the first step, the FY 2015 billing determinants

are used to map FY 2015 volumes to the FY 2006 categories. This can be done accurately because the FY 2015 billing determinants restate the FY 2015 volumes by the former sub-product breakouts. That is, both commercial and nonprofit Standard Mail volumes for FY 2015 are restated in their old ECR and Regular categories. This provides a direct mapping between the FY 2015 categories and the FY 2006 categories.

In the second step, an additional adjustment must be made as a result of the transfer of commercial Standard Parcels to the competitive sub-product Parcel Select under the title of "lightweight Parcel Select." As a result, a portion of FY 2015 Parcel Select volumes must be mapped to Standard Parcels. However, because there was substantial growth in Parcel Select since FY 2011, not all Parcel Select should be linked to Standard Parcels. Only the part of Parcel Select that migrated from Standard as a result of the reclassification should be mapped to Standard. That migration amount is estimated by calculating the difference between Standard Parcels in FY 2011, the year before the reclassification and FY 2012, the year after reclassification. The difference between those two volumes is 430.2 million pieces, which represents the volume of FY 2015 Parcel Select migrated back to Standard Parcels.[16]

16 All volume adjustments have a corresponding adjustment to shift costs. The cost estimated for Standard Parcels were based on publicly available information.

Table 2
Standard Mail Mapping

FY 2006 Categories	FY 2015 Categories
Enhanced Carrier Route	Enhanced Carrier Route from Reclassified FY 2015 Sub-Products
Regular	Regular from Reclassified FY 2015 Sub-Products Parcels that Migrated to Parcel Select

E.3 Mapping Periodicals

The categories for Periodicals did not change between FY 2006 and FY 2015, so no matching exercise was required. In both years the Periodicals product was split into In County and Outside County. Thus, the mapping for Periodicals is quite simple.

Table 3
Periodicals Mapping

FY 2006 Categories	FY 2015 Categories
In County	In County
Outside County	Outside County

E.4 Mapping Package Services

The Package Services product was divided three ways in FY 2006:

- Parcel Post
- Bound Printed Matter
- Media Mail

In FY 2015, the Package Services product was split between market dominant and competitive products, with three sub-products in each category:

- Bound Printed Matter Flats
- Bound Printed Matter Parcels
- Media and Library Mail
- Standard Post (Competitive)
- Parcel Return (Competitive)
- Parcel Select (Competitive)

The market dominant portion included two of the three components from FY 2006, Bound Printed Matter and Media Mail. By FY 2015, most of Parcel Post had been moved to competitive products and is split among three categories: Standard Post, Parcel Return Service, and Parcel Select.[17] Comparison across the years requires putting the FY 2015 market dominant and competitive categories together where appropriate. Bound Printed Matter Flats and Parcels are combined to match the full Bound Printed Matter category in FY 2006, and Media and Library Mail lines up with Media Mail. Standard Post roughly corresponds to the non-drop-shipped portion of the Parcel Post category.

This leaves the main issue of how to handle Parcel Select and Parcel Return Service.[18] Neither of these two FY 2015 sub-products existed as a separate sub-product in FY 2006. [redacted]. Fortunately, the billing determinants for FY 2006 provide sufficient detail to calculate the volumes for Parcel

17 International packages and Alaska Bypass are excluded from the analysis. Standard Post became “Retail Ground” in 2016.
18 In FY 2006, what is now Parcel Select type volume was included as a discounted rate category within Parcel Post. The Parcel Return Service experiment ended in March 2006 when it became a permanent classification.

Return Service and Parcel Select for that year. The FY 2006 billing determinants explicitly include volumes for Parcel Return Service, and these volumes can be directly applied.

The billing determinants for FY 2006 show what parts of Parcel Post were drop-shipped,[19] so the sum of the drop-shipped sub-products of Parcel Post can be reclassified as the volume for Parcel Select for FY 2006. Also, recall that a portion of the FY 2015 Parcel Select volumes are migrated from Standard Mail and are thus re-assigned to that product. Because neither Parcel Select nor Parcel Return Service existed as separate sub-products in FY 2006, we don't have marginal costs for those products in those years. (Moreover, Parcel Select is mostly drop-shipped to a destination facility and Parcel Return Service is picked up at a postal facility by the merchant, so the marginal costs for these two sub-products are appreciably smaller than the marginal cost for a traditional Parcel Post piece.) Thus, a method to estimate those two marginal costs must be found. We know that Parcel Post in FY 2006 was made up of three different sub-products: the single-piece part of Parcel Post (similar to what we now call Standard Post), Parcel Return Service, and Parcel Select. We also know that the marginal cost for overall Parcel Post is the volume-weighted average for the three individual products' marginal costs. This allows us to write the mathematical relationship that exists among the known marginal cost for parcel post, MC_{pp}, and the unknown marginal costs for Standard Post, MC_{SP}, Parcel Return, MC_{PR}, and Parcel Select, MC_{PS}:

19 Drop-shipping" occurs when a mailer transports the mail to the destination postal facility, saving the Postal Service the cost of intermediate sorting and transporting the mail. In this way, drop-shipped mail requires less work by the Postal Service.

$$MC_{pp} = \frac{MC_{SP}V_{SP} + MC_{PR}V_{PR} + MC_{PS}V_{PS}}{V_{SP} + V_{PR} + V_{PS}}.$$

We need to solve this expression for the unknown marginal costs. To do so, we make use of the fact that we have a value for MC_{pp} from the FY 2006 CRA and the volumes for Standard Post, V_{SP}, Parcel Return, V_{PR}, and Parcel Select, V_{PS}, from the FY 2006 billing determinants. But that is not enough information as it leaves us with a problem: one equation and three unknowns. Fortunately, we can pin down the solution by using the relative sizes of the three individual sub-product marginal costs. That is we can describe the marginal costs for Standard Post and Parcel Return Service as multiples of the marginal cost for Parcel Select:

$$MC_{SP} = \theta\, MC_{PS.}$$

$$MC_{PR} = \delta\, MC_{PS.}$$

For example, if the marginal cost for Parcel Return Service is 10 percent greater than the marginal cost for Parcel Select, then δ equals 1.10.[20]

We now have three equations in three unknowns and can solve for the unknown marginal costs. To do so we take the expressions for MC_{SP} and MC_{PR} and substitute them into the expression for MC_{PP}. We now have an expression with only one unknown, MC_{PS} :

20 Values for θ and δ are not available for FY 2006. The Postal Service has models that breakdown sub-product costs into finer groups that could provide estimates of these parameters, but the models are not available for FY 2006. They are available for FY 2007, but we also could use the values from FY 2008, the first year that separate marginal costs were calculated for Parcel Select and Parcel Return Service. Because they are based upon direct measurement instead of models, we chose the latter measure, but the choice does not change the pattern of results.

$$MC_{pp} = \frac{\theta\ MC_{PS}V_{SP} + \delta\ MC_{PS}V_{PR} + MC_{PS}V_{PS}}{V_{SP} + V_{PR} + V_{PS}}.$$

Applying some simple algebra allows us to solve for the marginal cost of Parcel Select in FY 2006:

$$MC_{PS} = \left(\frac{\sum_1^3 V_i}{\theta V_{SP} + \delta V_{PR} + V_{PS}}\right) MC_{PP.}$$

Once the marginal cost for Parcel Select is calculated, it is easy to calculate the marginal cost for the other two sub-products.

Table 4
Package Services Mapping

FY 2006 Categories	FY 2015 Categories
Non Drop-Shipped Parcel Post	Standard Post
Bound Printed Matter	Bound Printed Matter Flats Bound Printed Matter Parcels
Media Mail	Media and Library Mail
Parcel Return Service	Parcel Return Service
Drop-Shipped Parcel Post	Parcel Select Less Volumes Migrated from Standard Mail

F. Methodology for Measuring Marginal Cost Changes Due to Changes in Individual Product and Overall Volumes

There are four primary issues that must be addressed in developing a methodology for estimating the impact of volume changes on the Postal Service's marginal costs.

First, the methodology should address the issue that in a network with shared resources, there are two ways that changes in volume can affect a product's marginal cost: (1) changes in the product's own volume and (2) changes in the overall volume of the enterprise. The first effect is relatively straightforward. Product-specific economies of scale capture this effect, causing a product's marginal cost to rise or fall as its own volume decreases or increases. But, as mentioned above, when resources are shared, the cost of adding volume of one product depends upon the volumes of all other products. For example, higher volumes reduce the unit transportation costs for all products being transported, so adding a given amount of volume for a specific product will have a lower marginal cost when the volumes of all other products are high. A similar phenomenon holds for delivery in which the marginal cost of delivering another piece of mail (of any product) falls as the total volume of mail delivered rises. We address this issue by calculating both the single-product volume change effect and the overall volume-change effect on product marginal costs.

Second, the methodology must address the fact that the Postal Service does not have a single operation that provides all mail services, but a series of different operations that are required to accept, process, transport, and deliver the mail. This means that the Postal Service does not have a single relationship between cost and volume but rather a series of relationships reflecting the different operations required

to provide mail services. In other words, the different activities like mail processing, transportation, or delivery have different underlying cost functions and different economies of scale or density effects. Some activities may have little or no scale effects while other activities may have very large ones. This difference becomes an issue because different mail products make different "uses" of the various activities. Some products require substantial mail processing and transportation while others generate most of their costs in delivery. Therefore, accurately estimating the impact of volume level changes requires separately accounting for the individual scale effects in each activity as well as accounting for the product composition in each activity. We accomplish this disaggregated analysis by computing separate economies-of-scale effects for each Postal Service cost segment.[21]

In addition, this complexity means that the Postal Service does not have sufficient data to directly measure the amount of volume handled in each activity. It is not currently feasible, for example, for the Postal Service to count the number of pieces of mail carried on each truck. To measure marginal costs in these many activities, the Postal Service relies upon measures of intermediate output called "cost drivers." Cost drivers are typically a measure of intermediate output. Changes in the amounts of cost drivers directly impact costs and are correlated with changes in volume. For example, the number of pieces sorted on automatic equipment is a cost driver in mail processing;

21 A Postal Service cost segment is a collection of costs relating to a specific activity like city carrier street delivery.

or the number of pound-miles of mail flown is a cost driver in air transportation. The methodology must incorporate this use of cost drivers in calculating product costs.[22]

Third, the methodology should be consistent with the Postal Service's method of calculating product costs, yet still be tractable. The Postal Service has an extremely detailed and complex product cost model that, conceptually, could be directly used to estimate the effect of volume changes on marginal costs. However, such an effort would require simulating hundreds, if not thousands, of cost equations and relationships, and is well beyond the scope of this project. Instead, we follow the approach the Postal Service follows in its incremental cost model and assume the Postal Service cost structure can be acceptably approximated with constant elasticity functions, in which the applied elasticities come directly from the Postal Service's product cost model.[23] This allows us to capture the underlying nature of Postal Service's product cost while avoiding an excessive computational burden.

Fourth, the methodology should account for the fact that there were large volume changes between FY 2006 and FY 2015. Analyses of marginal costs typically focus on small volume changes, but we are interested in comparing marginal cost changes after substantial volume changes. We thus need a methodology that can account for large

22 For a full discussion of the Postal Service's product cost methodology, see United States Postal Service Office of Inspector General, RARC-WP-12-008, Primer On Postal Costing Issues (Mar. 20,2012), https://www.uspsoig.gov/sites/default/files/document-library-files/2015/rarc-wp-12-008_0.pdf.

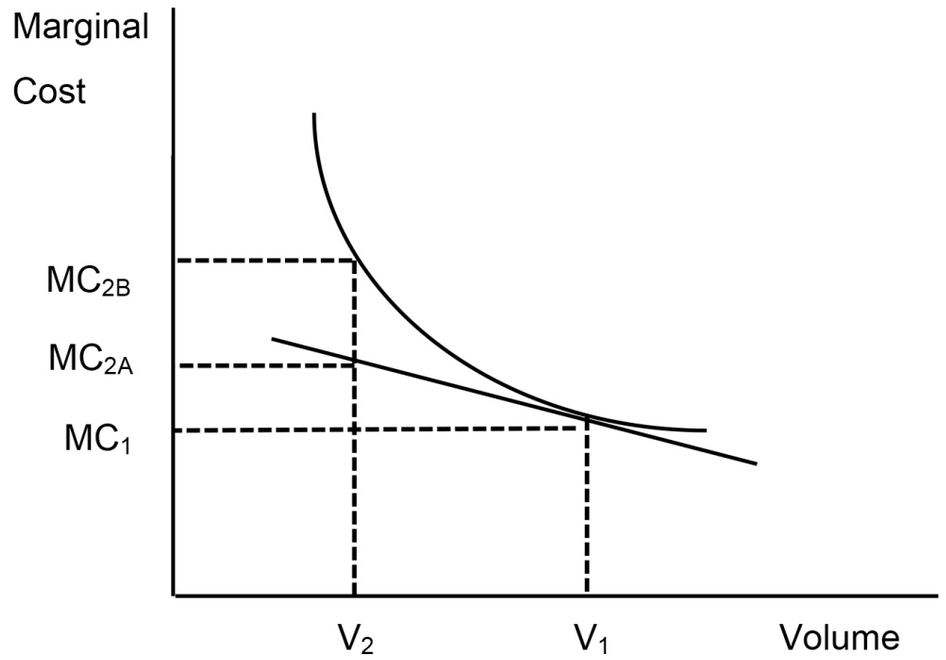
23 For each cost segment, a value for the elasticity of cost with respect to the driver is needed to calibrate the model. The elasticity can be found by dividing a segment's volume variable cost by its total accrued cost. The resulting elasticity is then used in the constant elasticity function. For a discussion of the implications of this assumption for measuring incremental costs, 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, pp. 3-21.

changes in volume. If we do not make this adjustment, we run the risk of understating the impact of volume change on marginal cost.

For example, one possible methodology is to compute the derivative (with respect to volume) of marginal cost and then multiply that derivative by the change in volume. This approach would be acceptable if the rate of change in marginal cost was truly constant (like for a quadratic function), but it is not acceptable when the rate of change in marginal cost is itself a function of volume. In these circumstances, assuming a constant change in marginal cost will lead to underestimation of the volume-induced change in marginal cost.

This is illustrated in Figure 1, which presents a curvilinear marginal cost schedule, consistent with a constant elasticity cost function. The initial volume level, V_1, has marginal cost MC_1 associated with it. The derivative of the marginal cost function at V_1, is graphically represented by the slope of the line tangent to the marginal cost curve at that volume. Now suppose volume falls to V_2. Application of the derivative method implies multiplying that change in volume by the rate of change in marginal cost to find what the marginal cost would be at the lower volume level. Graphically, this is shown by moving along the constant slope tangent line, producing an estimated marginal cost of MC_{2A}. In reality, the change in marginal cost is governed by the true total (and marginal) cost function. Using that function gives a higher marginal cost, MC_{2B}, at the lower volume, V_2. Use of the derivative method thus understates the true change in marginal cost caused by the volume decline.

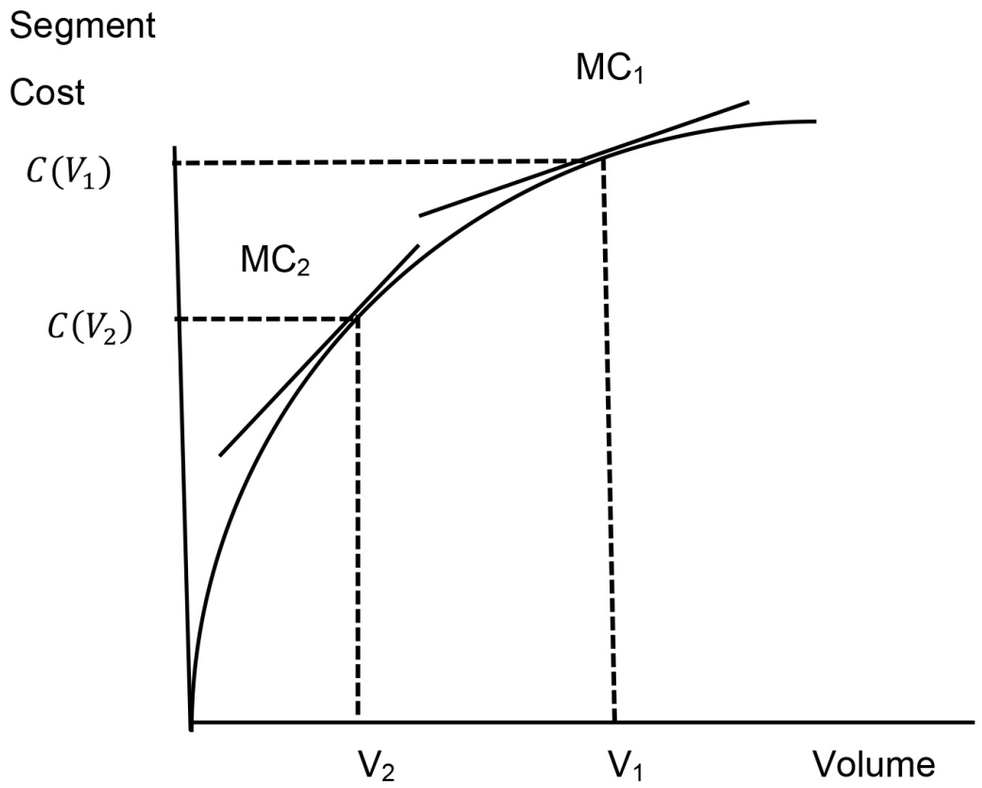
Figure 1
Using the Marginal Cost Curve to Calculate the Volume-Induced Change in Marginal Cost



To avoid this problem, we propose a methodology consistent with moving along the total cost function in each cost segment as volume changes. This methodology is illustrated in Figure 2, which relates levels of volume to levels of total segment cost.[24] At the initial volume level, $V_{1,}$ total segment cost is given by $C(V_1)$ and the associated marginal cost is given by the slope of the tangent to the cost curve at that volume. As volume falls to V_2, the methodology calculates the new total segment cost and the resulting new marginal cost at that volume point. Note the slope of the tangent is greater at V_2 than at V_1, reflecting the increase in marginal cost caused by the volume decline.

24 The complete methodology is presented in the Appendix.

Figure 2
Using the Total Cost Curve to Calculate the Volume-Induced Change in Marginal Cost



We apply this methodology in two ways. The first is associated solely with changes in an individual product's volume, while the second includes the change in all other volume that took place when the product's volume changed. This two-prong approach allows us to sort out the marginal cost changes coming from the two different volume changes.

In the case of the single product volume change, the calculation algorithm associated with this methodology has the following five steps. This five-step calculation is made separately for each of the cost segments in the Postal Service's product cost model:

Step 1: Calculate the base year marginal cost for each product by dividing the segment's volume variable cost, for each product, by its respective base year total volume for that product.

Step 2: Calculate the volume growth (or decline) rate for each product.

Step 3: Calculate the driver growth (or decline) rate for the cost driver.

Step 4: Use the change in the cost driver in the constant elasticity model to calculate the post-volume-change volume variable cost for each product.

Step 5: Calculate the post-volume-growth marginal cost by dividing the calculated volume variable cost by the post-growth volume.

The overall post-volume growth product marginal cost is found by summing the post-volume-growth segment marginal costs across the segments.

In the case of overall volume change, the five-step algorithm must be modified somewhat. Step 1 stays the same, but Step 2 must be broadened to calculate the rate of change in all volumes. Similarly, Step 3 must be broadened to account for the change in the driver due to changes in other volumes. In concept, Step 4 stays the same, but in measurement it changes because the amount of driver variation will be larger when all volumes change. Step 5 also remains the same.

G. Methodology for Measuring Marginal Cost Changes Due to Changes in Production Cost Levels

We have developed methodologies for measuring the impact of general inflation, workload variations due to mail mix changes, and changes in the levels of volume on marginal cost. Once these measurements have been made, we can calculate the impact of changes in the production cost level as the difference between the observed overall change in marginal cost and the sum of the measured changes for the other three reasons.

$$\Delta MC_{PCL} = \Delta MC - \Delta MC_{Inflation} - \Delta MC_{Workload} - \Delta MC_{Volume}.$$

Note that we do not directly calculate the marginal cost changes due to variations in production cost levels, but rather indirectly find it as the remaining unexplained change.

H. Implementing the Methodologies

Having developed the methodologies for calculating the impacts of various sources of change in marginal costs, we can now implement those methodologies to decompose the changes in Postal Service's marginal costs that occurred between FY 2016 and FY 2015. We perform the required calculations in a specific order, to both improve the transparency of the analysis and to ensure the different measures of marginal cost change are additively separable. That is, we want to be sure there is no double-counting or under-counting of marginal cost changes.

We first calculate the impact of inflation on marginal costs, to allow us to calculate inflation-adjusted FY 2015 marginal costs. This is important because those inflation-adjusted marginal costs are needed for subsequent calculations. We then calculate the cost effects of workload changes arising from product mix variations, because it produces inflation-adjusted FY 2015 marginal costs, free from the influence of mix changes.

These are exactly the cost measures needed to calculate the impact of volume changes, as those changes should be free from influences caused by product mix variations. We then calculate the effects of volume changes, both individual and

overall, on marginal costs and finish with the calculation of production cost level changes.

Before doing anything else, we need to find the actual change in overall marginal costs between FY 2006 and FY 2015. This requires obtaining the actual product marginal costs for the two fiscal years. For FY 2006, this is straightforward, as it amounts to extracting product marginal costs from the Postal Service's CRA report. The numbers in that report are the volume-weighted sums of the sub-products' marginal costs. Obtaining the product marginal costs for FY 2015 is more complicated. For Periodicals, the FY 2015 CRA marginal cost is the volume-weighted sum of the sub-products' marginal costs for that fiscal year, so it can be extracted directly from the report. For First-Class Mail, Standard Mail, and Package Services, the FY 2015 CRA marginal costs are not inclusive, and the overall marginal costs for these products must be calculated.

This calculation is required because, as discussed above, some of the sub-products that were in First-Class Mail and Package Services in FY 2006 are listed separately as competitive products in FY 2015 and because some Parcel Select volumes migrated from Standard Mail. The competitive sub-products must be reunited with the relevant market dominant sub-products, so that overall First Class and Package Service marginal costs for both fiscal years are consistent. As with the other actual costs, the calculated FY 2015 marginal costs for First Class and Package Services are the volume-weighted average of the sub-product marginal costs. Finally, the part of Parcel Select volumes that migrated from Standard Mail must be returned to Standard Mail.

Table 5 presents the nominal marginal costs, by product, for both FY 2006 and FY 2015. The difference between these two numbers, for each product, is the total observed change in marginal costs. For First Class, Standard, and Periodicals, the nominal marginal cost increased, but for Package Services it declined. Periodicals had the largest increase, at 7.5 cents. This represents a 26.3 percent increase. The marginal cost for Package Services fell by [redacted], representing a [redacted] percent decrease.

Table 5
Nominal Marginal Costs By Product

	FY 2006 Marginal Cost	FY 2015 Marginal Cost	Change
First Class	$0.1930	$0.2180	$0.0250
Standard	$0.1199	$0.1376	$0.0177
Periodicals	$0.2849	$0.3599	$0.0750
Package Services	$1.8236	[redacted]	[redacted]

We can now calculate the impact of inflation between FY 2006 and FY 2015 on the product marginal costs. As measured by the Consumer Price Index, inflation was 17.6 percent over that period, or, stated otherwise, 2006 prices were 85 percent of the 2015 prices.[25] This means that observed marginal costs would have increased substantially even if the "real" marginal costs did not change. Consequently, correcting

25 Note that during periods of inflation, the rate of price increase (17.6 percent) will necessarily be larger than the difference in the ratio of the older to current prices (15 percent). This is because the denominator for price growth is the older price and the denominator for the price ratio is the current price. During an inflationary period, the former is always smaller than the latter.

for inflation will reduce the size of the marginal cost increases, perhaps turning them to decreases, and will cause marginal cost decreases to be even larger (in absolute value). The inflation-adjusted marginal costs are presented in Table 6.

Table 6
Real Marginal Costs By Product

	FY 2006 Marginal Cost	FY 2015 Marginal Cost	Change
First Class	$0.1930	$0.1854	-$0.0076
Standard	$0.1199	$0.1170	-$0.0028
Periodicals	$0.2849	$0.3061	$0.0212
Package Services	$1.8236	[redacted]	[redacted]

Because FY 2006 serves as the base year for our analysis, the nominal and real marginal costs will be the same in that year. After adjusting for inflation, we see that the nominal marginal cost increases for First-Class Mail and Standard Mail become inflation-adjusted decreases. In other words, the increases in nominal marginal costs were less than they would have been if they had grown at the inflation rate. This means that First-Class Mail and Standard Mail marginal costs were growing slower than inflation, suggesting that real cost savings were rising. The real marginal cost for Periodicals increased by 7.4 percent, indicating that Periodicals costs were rising faster than inflation. The real marginal cost for Package Services fell by [redacted].

Another way to look at this same issue is to calculate the increase in the products' marginal costs that occurred due to inflation. That increase is the difference between their FY 2006 nominal marginal costs and their FY 2015 nominal marginal costs

that would have occurred if the marginal cost grew exactly at the inflation rate. Table 7 presents the increases in marginal cost due to inflation, ranging from 2 cents for Standard Mail to over 32 cents for Package Services.

Table 7
Change in Marginal Costs Due to Inflation

	FY 2006 Nominal Marginal Cost	FY 2015 Inflated Marginal Cost	Change In MC due to Inflation
First Class	$0.1930	$0.2269	$0.0339
Standard	$0.1199	$0.1409	$0.0211
Periodicals	$0.2849	$0.3350	$0.0501
Package Services	$1.8236	$2.1442	$0.3206

Source: FY 2006 nominal costs inflated to FY 2015.

We now calculate the impact on marginal costs from changes in workload due to product mix changes.[26] We do this by using the Fisher Ideal price index to calculate the growth in constant workload (and thus constant mix) marginal cost between the two years. An index value for the base year is 100, by definition. Thus, if we calculate a Fisher Ideal price index value of 105 for FY 2015, we can conclude that the constant workload marginal cost increased by 5 percent, which is the percentage difference in the two index values. If we define that growth rate as ρ, we can calculate the constant workload marginal cost for FY 2015 as: (1+ρ) * (FY 2006 Marginal Cost). This approach allows us to distinguish between declines in marginal cost that occur because

26 Because we are making two adjustments to the products' marginal cost, a natural question is whether the results are dependent upon the order in which the adjustments are made. In our case they are not. If we first adjusted for workload and then corrected that workload adjustment for inflation, we would end up with the same amount of adjustment as we find in the current procedure.

of productivity improvement and declines in marginal cost that occur because less work is required to provide a product.[27]

This exercise calculates the marginal cost for a constant workload. For example, if a product's workload has decreased because the presorted portion of the product has grown relative to the non-presorted portion, then the constant workload marginal cost will increase more than the observed one. In other words, the actual FY 2015 marginal cost fell due to the reduced workload; controlling for that change would cause the corrected FY 2015 marginal cost to be higher. Table 8 presents the workload adjusted marginal costs. It also presents the effect of the workload changes on product marginal cost which is just the difference between the inflation and workload adjusted marginal costs and the inflation adjusted marginal costs (from Table 6).

Table 8
Change in Marginal Costs Due to Workload Changes

	FY 2015 Inflation Adjusted Marginal Cost	FY 2015 Inflation & Workload Adjusted Marginal Cost	Change in MC Due to Workload Change
First Class	$0.1854	$0.1998	-$0.0144
Standard	$0.1170	$0.1166	$0.0004
Periodicals	$0.3061	$0.3088	-$0.0028
Package Services	[redacted]	[redacted]	[redacted]

27 As mentioned above, there can be workload changes within a sub-product if the characteristics of the sub-product change. Our workload adjustment controls for changes in the mix of sub-products but not changes in sub-product characteristics. Those changes are included in changes in production cost levels.

The workload adjusted marginal costs are higher for First Class, Periodicals, and Package Services, indicating that all three products experienced a change in mail mix which led to a reduced average workload. In Periodicals, the proportion of In County, which has a lighter workload, rose from 8.4 percent to 9.8 percent. In Package Services, the growth in drop-shipped Parcel Select substantially reduced the average workload per piece. The only exception to a reduced workload was Standard Mail, in which the proportion of Enhanced Carrier Route mail fell slightly from 34.8 percent to 33.4 percent.[28]

Table 8 also shows that by 2015, the increased proportion of presort mail reduced the average marginal cost for First-Class Mail by 1.4 cents, and [redacted] Both of these figures are in inflation-adjusted dollars. In FY 2015 dollars, those two workload-related changes would be larger, with a decrease of 1.7 cents for First-Class Mail and [redacted].[29]

Next we calculate the effects of volume changes on marginal costs. To keep our measures of total volume effects free of mix (and thus workload) effects, we will compute the total volume level changes holding the volume mix constant. This requires remapping the FY 2015 product volumes into the FY 2006 categories, and we follow the same methods detailed in the previous section. Table 9 presents the various rates of change in product volumes between FY 2006 and FY 2015.

28 Part of the reduction in Enhanced Carrier Route came from a reclassification of FSS flats that moved them to Standard Mail.

29 [redacted].

Table 9
Volume and Growth Rates of Change for FY 2006 Products

FY 2006 Categories	FY 2006 Volumes (000s)	Remapped FY 2015 Volumes (000s)	Change
First-Class Mail			
Single-Piece Letters	42,064,524	21,131,949	-49.76%
Presort Letters	49,862,002	39,187,352	-21.41%
Single-Piece Cards	2,301,043	838,954	-63.54%
Presort Cards	3,386,571	2,169,537	-35.94%
Total First Class	**97,614,139**	**63,327,792**	**-35.12%**
Standard Mail			
Enhanced Carrier Route	35,651,264	26,910,300	-24.52%
Regular	66,808,295	53,610,184	-19.76%
Total Standard Mail	**102,459,559**	**80,520,484**	**-21.41%**
Periodicals			
In County	757,928	570,817	-24.69%
Outside County	8,264,634	5,267,358	-36.27%
Total Periodicals	**9,022,562**	**5,838,175**	**-35.29%**
Package Services			
Parcel Post	362,727	[redacted]	[redacted]
Bound Printed Matter	618,685	488,404	-21.06%
Media Mail	193,136	74,890	-61.22%
Total Package Services	**1,174,548**	[redacted]	[redacted]

We use these rates of change to calculate the impact on individual products' marginal costs due to the individual volume changes. The first set of results is solely the products' marginal cost responses to changes in the product's own volume, without accounting for the fact that other volumes were also changing. Table 10 presents the calculated post-volume marginal costs along with the absolute and percentage changes in those costs.

The first thing to note about the results is that, as expected, those products with volume declines had marginal cost increases, and vice versa. A second observation is that the percentage changes in marginal costs are dampened relative to the volume swings.

Table 10
Impact on Product Marginal Cost of Individual Volume Change

FY 2006 Categories	Base Year MC	Individual Volume Growth MC	MC Change due to Volume Change	% Change
First-Class Mail				
Single-Piece Letters	0.2983	0.3131	0.0148	4.95%
Presort Letters	0.1111	0.1122	0.0011	0.96%
Single-Piece Cards	0.2193	0.2200	0.0006	0.29%
Presort Cards	0.0732	0.0733	0.0001	0.10%
Total First-Class Mail	**0.1930**	**0.2035**	**0.0105**	**5.43%**
Periodicals				
Within County	0.1091	0.1092	0.0000	0.03%
Outside County	0.3010	0.3027	0.0018	0.58%
Total Periodicals	**0.2849**	**0.2866**	**0.0017**	**0.60%**
Standard Mail				
Enhanced Carrier Route	0.0862	0.0874	0.0012	1.35%
Regular	0.1378	0.1399	0.0020	1.45%
Total Standard Mail	**0.1199**	**0.1230**	**0.0031**	**2.58%**
Package Services				
Parcel Post	3.1250	[redacted]	[redacted]	[redacted]
Bound Printed Matter	0.8999	0.9011	0.0012	0.13%
Media Mail	2.3382	2.3423	0.0042	0.18%
Total Package Services	**1.8236**	[redacted]	[redacted]	[redacted]

This difference in percentage changes may appear surprising initially, but consideration of the different parts of the impact of volume changes on costs in the

Postal Service's cost model explains why it occurs. As expected, total volume variable costs fall, but they decline less than volume, putting upward pressure on unit costs. A decline in volume for, say, Product X means that the proportion of the volume variable costs going to the product is falling. This mitigates the impact of the increase in unit cost from volume declines. In essence, because of shared production, the increase in unit cost due to a decline in Product X's volume is "shared" by all products and not just concentrated in the change in marginal cost for that product.

For example, consider First-Class Mail, which had a volume decline of 35 percent, but a marginal cost increase of 5 percent. Initially, it is important to recognize that although First-Class Mail volume declined by 35 percent, the cost driver in any activity declined by a far smaller percentage. This is because First-Class Mail averages about 40 percent of driver usage. Keeping in mind this proportional relationship, a 35 percent decline in First-Class Mail volume leads to only a 14 percent decline in the amount of the driver used.

Consequently, marginal cost will rise, because the amount of the driver and overall volume variable cost will decline less than volume. If the variability for a cost segment is 65 percent, a 14 percent decline in the driver causes a 9 percent decline in total cost. So the 35 percent decline in First-Class Mail volume caused only a 9 percent decline in a segment's cost.

But there is an additional effect. When a product's volume declines, its share of the cost driver also declines. In the case of First-Class Mail, the 35 percent volume decline causes its driver proportion to fall from 40 percent to just 30 percent. This reduction causes First-Class Mail's volume variable cost to fall by 31.5 percent, partially

offsetting the overall increase in marginal cost. In other words, First-Class Mail's new volume variable cost is 68.5 percent of its old value, while its new volume is 65 percent of its old value. *The differences in these percentages is what makes marginal cost rise.* The ratio of 68.5 to 65 is 1.053, indicating that marginal cost will rise by 5.3 percent. Thus we see how a 35 percent decline in volume leads to only a 5 percent increase in marginal cost.

To make this more concrete, consider a particular activity, such as highway transportation. A fall in First Class volume means the Postal Service transports less mail and it shows up as a reduction in the highway transportation cost driver — cubic foot-miles. However, more than First-Class Mail is transported on trucks, so the fall in cubic foot-miles has a smaller proportional reduction than the fall in First Class volume. Further, scale economies in transportation mean the associated decline in cost is proportionally smaller than the fall in cubic foot-miles. Taken together, these effects mean the marginal transportation cost of First-Class Mail will rise, as volume is falling faster than cost. But also note that First Class volume is now smaller relative to the other products and, consequently, First Class has a smaller proportion of cubic foot-miles than before. This mitigates the marginal cost increase for First Class and means that a substantial fall in First-Class Mail volume may lead to an increase in marginal cost that is attenuated relative to the fall in volume.

This effect is even more pronounced for small volume products such as Periodicals and Package Services. For example, if a 100 percent increase in the volume of Package Services leads to only a 3 percent increase in the typical cost driver, then this increase in volume would lead to a 190 percent increase in the proportion of the cost

driver going to Package Services. Although total volume variable cost would increase by just 3 percent, the volume variable cost for Package Services would increase by 97 percent because of the change in this proportion. The new Package Services volume variable cost would be 197 percent of its old value, while the new Package Services volume would be 200 percent of its old value, pushing down marginal cost by just 1.5 percent.[30]

We also want to investigate the impact of volume changes on marginal costs when all volumes changed at their actual rates over the study period. To do this, we look at a change in marginal cost that comes about from both a change in Product X's volume and a change in the Postal Service's overall volume level. To measure this change, we allow Product X and all other products to grow or contract at their historical rates from FY 2006 through FY 2015. However, because we want to control for changes in mix (whose effects were measured previously), it is essential that all parts of a product group grow at the same rate. Otherwise the computed cost changes would include both the effect of changes in product mix and the effect of volume changes. Thus, for *this* specific calculation we specify that all sub-products decline at that product rate. Note that our overall analysis is *not* assuming that all sub-products decline at the overall product rate. Rather, the differential actual growth or decline rates are accounted for in the product mix calculation.

We must also slightly modify the computational formula to account for the fact that volumes for all products are changing. This modified formula is presented in the

30 As with any such computation, this result would be partly dependent on the structure of the model in which it takes place. These hypothetical quantitative results thus would partly depend on the structure of the Postal Service's product cost model and the fact that the analysis would be done at the cost segment level.

Appendix. Table 11 presents the marginal cost associated with changes in all volumes, along with the decomposition of the change into the part from the products' own volume change and the overall volume decline.

Table 11
Identifying Different Volume Related Sources of MC Change

	Scale Adjusted Marginal Costs	MC Change Total Volume-Related	MC Change From Individual Volume Change	MC Change From Overall Volume Decline
Total First-Class Mail	$0.2081	$0.0151	$0.0105	$0.0046
Total Standard Mail	$0.1301	$0.0103	$0.0031	$0.0072
Total Periodicals	$0.3041	$0.0192	$0.0017	$0.0175
Total Package Services	[redacted]	[redacted]	[redacted]	[redacted]

This shows that there is a modest additional effect on First-Class Mail from including the overall volume change; First-Class Mail represents a large proportion of total volume, so its own volume declines already incorporate a relatively large overall volume decline. In contrast, the additional effect is large for both Periodicals and Package Services. Because of its tiny size, the decline in Periodicals volume alone had very little effect on its marginal cost, but the overall decline in volume has a much more

substantial impact.[31] This is because Periodicals "share" the impact, in terms of higher marginal cost, of the decline in First Class and Standard volumes.

To see how this effect works, consider a letter carrier route that has large volumes of both First-Class Mail and Standard Mail. Because of those large volumes, the carrier is continually deviating from the core portion of her route to access houses and business in order to deliver the mail. As a result, she is walking to virtually every address on the route. The additional delivery cost of another magazine (Periodical) is quite small, because it only involves the time required to put the magazine in the mail receptacle. Because the carrier was going to virtually every house anyway, an additional magazine is very unlikely to cause any additional walking time. But now suppose that First Class and Standard volumes fall, so that the carrier is walking to only half of the addresses on the route. Now, an additional magazine is quite likely to cause the carrier to go to an address that was getting no other mail. The marginal cost of the magazine is higher because it caused both the loading time and the time it took the carrier to walk to the door. In this way, the decline in First Class and Standard volume caused an increase in the marginal cost of Periodicals.

This effect is even more pronounced for Package Services, because it experienced an increase in volume while total volume was declining. The lower marginal cost associated with increasing Package Services volume is more than offset by the increase in marginal cost caused by declining system-wide volume, leading to an overall increase in Package Services' marginal cost. This increase occurs because of the shared cost nature of activities like transportation or delivery. For example, as volume falls, the cost of providing transportation per cubic foot-mile rises, regardless

31 A mathematical analysis of this result is presented in the Mathematical Appendix.

of which products are being transported. Lower volume means it becomes more expensive for the Postal Service to transport all of its mail, and those higher costs apply to Package Services, to the extent the volume is not drop-shipped. In addition, as the proportion of mail made up by Package Services rises, its cost responsibility for the transportation network rises. The same process is true in delivery. A decline in volume raises the unit cost of delivery of all mail, including the delivery of packages.

We can now calculate the changes in marginal cost due to production cost levels. The marginal cost change is just the difference between the total observed change in marginal cost for a product and the sum of the changes coming from all other sources, including inflation, workload, and volume changes. A decline in marginal cost from production cost level variations implies that the combination of technology changes, productivity enhancements, input cost variations, and reorganization of activities has caused the marginal cost curve to shift down. This, in turn, implies lower marginal costs at existing volume levels. Table 12 presents the changes in marginal costs from changes in production cost levels, along with the changes from all other sources.

Table 12
Sources of Change in Marginal Costs

	First Class	Standard	Periodicals	Package Services
Observed Change in Marginal Cost	$0.0250	$0.0177	$0.0750	[redacted]
Change in Marginal Cost From Inflation	$0.0339	$0.0211	$0.0501	$0.3206
Change in Marginal Cost From Workload Change	-$0.0144	$0.0004	-$0.0028	[redacted]
Change In Marginal Cost From Individual Volume Change	$0.0105	$0.0031	$0.0017	[redacted]
Change In Marginal Cost From Overall Volume Decline	$0.0046	$0.0072	$0.0175	[redacted]
Change in Marginal Cost From Changes in Production Cost Levels	-$0.0097	-$0.0140	$0.0085	[redacted]

For the most part, the changes in marginal cost from production cost level changes are relatively modest, indicating that the other factors are explaining most of the variations in marginal costs. For First-Class Mail, Standard Mail, and Package Services, the negative production level change indicates that the level of production costs for those products have shifted down due to a combination of reduced service, lower wages, improved productivity, and changes in the nature of the products. For example, some of the decline in Standard Mail marginal cost could reflect a reduction in the proportion of flats relative to letters in the Standard Mail stream. Similarly, to the extent that weight matters for marginal cost, the decline in Package Services marginal cost could partially reflect the growth in lightweight Parcel Select volume; another part

could reflect an increase in the amount of drop-shipping. Finally, the decline in the First-Class Mail marginal cost could partially reflect reduced service standards for that product. These are important issues for future research, particularly because the current methodology does not provide a way to disentangle the different factors.

I. Assessing the Constant Elasticity Assumption

One concern with the constant elasticity approach followed here is the degree to which the assumption of constant elasticity may be influencing the results. If the elasticity were to change when volume changes, the natural question is what impact this change would have on the marginal cost response. To investigate this concern, we pursued a sensitivity analysis on the calculated marginal cost responses.

Specifically, we varied each cost segment's elasticity to assess the impact that a change in elasticity would have on the calculated results. At the bottom end, we reduced all of the component elasticities by 5, 10, and 15 percentage points, and at the upper end we increased all of the component elasticities by 5, 10, and 15 percentage points.[32] This allows the overall elasticity to range between 44 percent and 74 percent, which would seem to cover any likely responses in the elasticity to volume changes. The results of the sensitivity analysis are presented in Table 13. The reported changes in marginal cost include both the responses to individual volume changes and the responses to overall volume changes.

32 On the lower end, we do not allow any component elasticities to fall below zero, and at the upper end we do not allow any elasticities to rise above 100 percent.

Table 13
Sensitivity Analysis of The Change in Marginal Costs Arising from Volume Changes

Change in Component Elasticities	Total First-Class Mail	Total Standard Mail	Total Periodicals	Total Package Services
-15%	$0.0226	$0.0150	$0.0294	[redacted]
-10%	$0.0200	$0.0134	$0.0260	[redacted]
-5%	$0.0176	$0.0118	$0.0226	[redacted]
0%	**$0.0151**	**$0.0103**	**$0.0192**	[redacted]
5%	$0.0127	$0.0087	$0.0159	[redacted]
10%	$0.0103	$0.0072	$0.0127	[redacted]
15%	$0.0079	$0.0057	$0.0094	[redacted]

As the elasticity rises, the marginal cost responses fall. At high elasticities, reductions in volume have relatively small effects on marginal costs, because the underlying scale effects are small. At high elasticities, the marginal cost curve is “flat,” meaning that the marginal cost does not rise much with volume declines. In contrast, at low elasticities the marginal cost curve is “steep,” and volume declines can cause relatively large increases in marginal costs. Extreme variations in the elasticities do cause the measured marginal cost responses to change, but not by dramatic amounts. The range for First-Class Mail is from just under 1 cent to 2 cents. For Standard Mail, the rage is from about 0.5 cent 1.5 cents. The range for Package Services is larger, but that product’s marginal cost is measured in dollars, not cents.

The results of the sensitivity analysis suggest that the constant elasticity assumption is not solely responsible for the results. Most likely any elasticity changes due to volume changes would be in the range of 5 to 10 percent, and Table 13 shows the resulting changes in marginal cost response are modest.

J. Observations

We have for the first time, to our knowledge, developed a methodology for measuring the different sources of change in Postal Service product costs. We applied that methodology to examine the important sources of change in the marginal costs for the Postal Service's main products over the period from 2006 to 2015.

A number of interesting results emerged from the analysis. First, three of the Postal Service's four main products experienced actual marginal cost increases at a rate which was slower than the overall rate of inflation. For First-Class Mail and Package Services, this happened, in part, because these products' average workloads fell due to a change in product mix towards lower work content sub-products. At the same time, volume declines caused increases in marginal costs for all products.

Large volume products, First-Class Mail and Standard Mail, experienced increasing marginal costs due to declines in their own volumes. Smaller volume products, such as Periodicals and Package Services, experienced increases in their marginal costs due to decline in overall volume levels. Finally, most products experienced reduction in their production cost levels. This means that the Postal Service, through a combination of lower wages, increased productivity, changing product characteristics, improved technology, network rationalization, and lower service

standards, was able to have lower marginal costs for those products at all volume levels.[33] Investigation of these sources of change is an important topic for future research.

The analysis in this report is necessarily historical, as it examines changes in marginal costs that have actually occurred. Lessons can be learned from this exercise, but caution should be exercised when attempting to extrapolate these results into the future.

For example, the Postal Service has rising marginal cost pressure due to volume declines, but has been able to, for the most part, offset those marginal cost increases with production cost level reductions. However, that it has done so in the past does not ensure that it will be able to do so in the future. Why not?

First, the rate of increase in marginal costs caused by volume declines tends to increase as volume continues to decline. When volume starts to decline, the increases in marginal cost are modest, but as volume continues to decline, marginal cost rises at a faster rate. Second, the Postal Service most likely first found the productivity gains and cost reductions that provided it with the "biggest bang for the buck." Future efforts may not be able to lower marginal costs as much as current experience.

Further, adjustments to changing volumes can sometimes create bottlenecks and adjustment costs. Over the period of our analysis, the Postal Service appears to have been successful in absorbing a doubling in Package Services volume without increasing its product costs. If package volume continues to grow, the Postal Service may face

33 Changes that increase marginal cost can also occur. For example, the number of delivery points to which the Postal Service delivers mail increased by 6 percent during the period from FY 2006 to FY 2015.

additional challenges in integrating that additional volume into its system in a way which continues the reduction in product cost levels.

Appendix

The methodology applied in this paper makes use of the Postal Service's product cost structure. Product marginal costs are calculated for each cost segment and summed across segments to find the overall product marginal costs. In this mathematical appendix, the methodology is illustrated for one cost segment, but in calculating marginal costs, it is applied to all cost segments.

The goal is to calculate the change in marginal cost arising from a change in volume. To accomplish this, we calculate the post-volume change marginal cost using the same methods that are applied to find the pre-volume change marginal cost by the Postal Service. For simplicity, we call the pre-volume change marginal cost the "base year."

Applying the constant elasticity approximation to the cost segment implies that total segment costs can be expressed as a function of the amount of the cost driver. We use the "B" superscript to indicate base year costs and the "i" subscript to indicate we are analyzing the "ith" cost segment. Specifically, total cost for the "ith" segment in the base year, (C_i^B) is given by:

$$C_i^B = \alpha_i \left(D_i^B\right)^{\varepsilon_i}.$$

Both α and ε are parameters and are not affected by a volume change. D_i^B is the amount of the cost driver used in the segment and is the sum of the individual amounts of the cost driver used by the various "M" products:

$$D_i^B = D_{iX}^B + D_{iY}^B + D_{iZ}^B + \ldots + D_{iM}^B .$$

The volume variable (or attributable) cost for Product X in the base year is given by:

$$VVC_{iX}^B = C_i^B \varepsilon_i \theta_{iX}^B, \qquad where\ \theta_{iX}^B = \frac{D_{iX}^B}{D_i^B}.$$

Dividing Product X's segment volume variable cost by its volume produces its segment marginal cost:

$$MC_{iX}^{B} = \frac{C_i^B \varepsilon_i \theta_{iX}^B}{V_X^B} = \frac{\varepsilon_i \alpha_i \left(D_i^B\right)^{\varepsilon_i} \frac{D_{iX}^B}{D_i^B}}{V_X^B}.$$

Suppose that Product X grows at rate g_x over the time period of analysis. Then the volume in the current year is given by:

$$V_X^C = (1 + g_x)V_X^B.$$

To calculate the marginal cost implied by this volume change, we must first calculate the impact of the volume change on Product X's volume variable cost. As the above formula indicates, that requires analyzing the impact of the volume change on both total segment cost and Product X's proportion of the driver. To make both of these calculations, we must first determine how much the cost driver grows in response to the volume growth.

We know that in this case, the driver grows only in response to the change in the volume of Product X. Thus, we can focus solely on the change in the amount of driver used by Product X. In other words, the post-volume-change amount of the driver:

$$D_i^C = D_{iX}^C + D_{iY}^B + D_{iZ}^B + \ldots + D_{iM}^B .$$

If Product X is changing at rate then how fast is changing? To determine that amount, we follow the assumption in the Postal Service's product cost model that specifies that the amount of the driver used by a product changes in proportion to any change in the product's volume. In other words, the ratio of the product's driver amount to its volume is set by technology or other factors, but not by the level of volume. This assumption implies that the rate of change in the driver used by Product X is the same as the rate of change in the volume of Product X, or

$$D_{iX}^C = (1 + g_x)D_{iX}^B.$$

Substitution yields:

$$D_i^C = (1 + g_x)D_{iX}^B + D_{iY}^B + D_{iZ}^B + \ldots + D_{iM}^B.$$

But we know the relationship between the amount of the driver used by Product X and the total amount of the driver used in the base year is given by:

$$D_{iX}^{B} = \theta_{iX}^{B} D_{i}^{B}.$$

This allows us to write the post-volume-growth amount of the driver as:

$$D_{i}^{C} = \left(g_x \theta_{iX}^{B}\right) D_{i}^{B} + D_{i}^{B} = \left(1 + g_x \theta_{iX}^{B}\right) D_{i}^{B}.$$

Derivation of the post-volume-change amount of the driver permits us to calculate both the resulting total segment cost and segment driver proportion, both of which are necessary for calculating the post-volume-change volume variable and marginal costs for Product X. After the volume change, total segment costs becomes

$$C_{i}^{C} = \alpha_i \left(D_{i}^{C}\right)^{\varepsilon_i} = \alpha_i \left(\left(1 + g_x \theta_{iX}^{B}\right) D_{i}^{B}\right)^{\varepsilon_i}.$$

The post-volume-change proportion of the driver used by Product X is given by:

$$\theta_{iX}^{C} = \frac{(1 + g_x) D_{iX}^{B}}{(1 + g_x \theta_{iX}^{B}) D_{i}^{B}} = \left(\frac{1 + g_x}{(1 + g_x \theta_{iX}^{B})}\right) \theta_{iX}^{B}.$$

With these two expressions, we can solve for the post-volume-change volume variable cost for Product X:

$$VVC_{iX}^{C} = \varepsilon_i \alpha_i \left(\left(1 + g_x \theta_{iX}^{B}\right) D_{i}^{B}\right)^{\varepsilon_i} \left(\frac{1 + g_x}{(1 + g_x \theta_{iX}^{B})}\right) \theta_{iX}^{B}.$$

Dividing by post-change volume provides an analytical formula for the post-change marginal cost:

$$MC_{iX}^{C} = \frac{\varepsilon_i \alpha_i \left(\left(1 + g_x \theta_{iX}^{B}\right) D_{i}^{B}\right)^{\varepsilon_i} \left(\frac{1 + g_x}{(1 + g_x \theta_{iX}^{B})}\right) \theta_{iX}^{B}}{(1 + g_x) V_{X}^{B}}.$$

This can be simplified to provide a straightforward computational formula:

$$MC_{iX}^{C} = \left(1 + g_x \theta_{iX}^{B}\right)^{\varepsilon_i - 1} MC_{iX}^{B}.$$

We also need to derive the computational formula for the case in which all volumes change. We start that derivation with the expression for the post-volume change amount of the driver:

$$\widehat{D}_i^C = (1 + g_x) D_{iX}^B + \left(1 + g_y\right) D_{iY}^B + (1 + g_z) D_{iZ}^B + \ldots + (1 + g_m) D_{iM,}^B$$

or,

$$\widehat{D}_i^C = \sum_{j=1}^{M} (1 + g_j) D_{ij}^B = D_i^B \left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^B g_j\right)\right).$$

With this expression, we can now derive both the total segment cost and the driver proportion that arise after the post volume change.

$$\hat{C}_i^C = \alpha_i \left(\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^B g_j\right)\right) D_i^B\right)^{\varepsilon_i}.$$

$$\hat{\theta}_{iX}^C = \left(\frac{1 + g_x}{1 + \sum_{j=1}^{M} \left(\theta_{ij}^B g_j\right)}\right) \theta_{iX}^B.$$

As before, these two pieces allow us to derive the new volume variable cost:

$$\widehat{VVC}_{iX}^{C} = \varepsilon_i \, \alpha_i \left(\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^{B} g_j \right) \right) D_i^B \right)^{\varepsilon_i} \left(\frac{1 + g_x}{\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^{B} g_j \right) \right)} \right) \theta_{iX}^{B},$$

and marginal cost:

$$\widehat{MC}_{iX}^{C} = \frac{\varepsilon_i \, \alpha_i \left(\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^{B} g_j \right) \right) D_i^B \right)^{\varepsilon_i} \left(\frac{1 + g_x}{\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^{B} g_j \right) \right)} \right) \theta_{iX}^{B}}{(1 + g_x) V_X^B}.$$

We can use the two marginal cost formulas to examine the relative sizes of the two effects. The ratio of the post volume change marginal cost when all volumes change to the post volume change marginal cost change when just a single product's volume changes is given by:

$$\frac{\widehat{MC}_{iX}^{C}}{MC_{iX}^{C}} = \frac{\dfrac{\varepsilon_i \, \alpha_i \left(\left(1 + g_x \theta_{iX}^{B} \right) D_i^B \right)^{\varepsilon_i} \left(\dfrac{1 + g_x}{\left(1 + g_x \theta_{iX}^{B} \right)} \right) \theta_{iX}^{B}}{(1 + g_x) V_X^B}}{\dfrac{\varepsilon_i \, \alpha_i \left(\left(1 + \sum_{j=1}^{M} \left(\theta_{ij} g_j \right) \right) D_i^B \right)^{\varepsilon_i} \left(\dfrac{1 + g_x}{\left(1 + \sum_{j=1}^{M} \left(\theta_{ij} g_j \right) \right)} \right) \theta_{iX}^{B}}{(1 + g_x) V_X^B}}$$

This can be simplified to

$$\frac{\widehat{MC}_{iX}^{C}}{MC_{iX}^{C}} = \frac{\left(1 + \sum_{j=1}^{M} \left(\theta_{ij}^{B} g_j \right) \right)^{\varepsilon_i - 1}}{\left(1 + g_x \theta_{iX}^{B} \right)^{\varepsilon_i - 1}}.$$

Analysis of the denominator of this expression shows that if a product's volume is relatively small, so is relatively small, then the own volume effect will also be small and the ratio of the overall effect to the own volume effect will be large. In other words, like we observe for Periodicals and Package Services, the change in marginal cost from overall volume declines will be large relative to the change in marginal cost from the product's own volume change.

Appendix: Management's Comments

SHARON OWENS
VICE PRESIDENT, PRICING AND COSTING

UNITED STATES POSTAL SERVICE

March 1, 2017

RENEE SHEEHY
DIRECTOR, RARC CENTRAL
RISK ANALYSIS RESEARCH CENTER

SUBJECT: Examining Changes in Postal Product Costs
2016RARC010

Dear Ms. Sheehy,

The Postal Service appreciates the opportunity to review the white paper, Examining Changes in Postal Product Costs, prepared by the USPS OIG Risk Analysis Research Center. It was refreshing to see the question of "what caused costs to change" be reframed in a broader context and not solely focused on a question of costing methodology or costing theory. The paper provided a broader range of causative variables and certainly suggested that establishing what "caused costs to change" is not an easy task, neither conceptually nor mathematically.

Thank you for the opportunity to review the report and the associated research paper.

Sharon Owens
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