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Freight Rail Costing and Regulation: The Uniform Rail Costing System

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Abstract Railroad regulation in the post-Staggers Act regime compares the revenues earned to a measure of the "variable cost" of the shipment. While revenues are readily observed, the "variable cost" is calculated using the "Uniform Rail Costing System" (URCS) that was developed by the Interstate Commerce Commission. We characterize the properties of the URCS rail costing methodology and its role in rate regulation, and we assess whether it produces an economically valid estimate of the cost caused by a rail shipment. We find that the URCS methodology is an accounting cost allocation procedure that does not recover an estimate of the cost of a rail shipment that a rational railroad operator would use to make pricing or operating decisions. We then explain why in the post-Staggers Act regime, even if an economic meaningful shipment cost measure were available, this information would not come any closer to solving the problem of determining what is an unreasonable price for a railroad to charge. We conclude by arguing that the use of the URCS methodology should be abandoned in railroad rate reasonableness regulation and replaced with a price benchmarking approach.

Keywords URCS · Railroad regulation · Stand-Alone Costs

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1 Introduction

The declining financial health of railroads in the post-World War II period and several high-profile railroad failures in the 1970s led to a series of legislative efforts that were intended to allow railroads to achieve revenue adequacy. These reforms culminated with the passage of the Staggers Rail Act of 1980.[1] The major changes implemented are: (1) greater pricing flexibility for railroads; (2) the ability to sign confidential negotiated contracts between railroads and shippers; and (3) reduced impediments to mergers and track abandonments.[2] Because of the financial condition of the industry at the time, these reforms also require an annual determination of whether each railroad is "revenue adequate": whether it has achieved a rate of return that is sufficient to attract the capital that is necessary for its long-term financial viability.

Under Staggers, a railroad can set the rate for a shipment at any level. Once issued, a rate can be challenged only if it exceeds a legislatively defined value and the railroad is found to lack effective competition in the market for this shipment, which is defined in the law as the railroad having "market dominance". A rate that is eligible for challenge could still ultimately be judged legal, or "reasonable," by regulators if the railroad was not found to be market dominant. Only when the legislative rate threshold is violated and the railroad is found to be market dominant is the rate subject to regulation.

Staggers also provides a blanket exemption on rate regulation for shippers that negotiate private contractual terms with the railroad providing service. Because these rates are the result of a presumably voluntary negotiation, they cannot be challenged. Many commodities are exempt from rate challenges because they can be competitively moved by truck. Staggers also relaxed the standards for allowing railroad mergers and streamlined procedures for selling and abandoning rail lines.

The impact of these changes on the industry has been dramatic, with significant reductions in operating costs and rail rates, the removal of uneconomic capacity, the introduction of many new services, and greater industry consolidation.[3] Overall, these changes have resulted in a substantial improvement in the financial health of the freight rail sector, which is consistent with the goals of the Staggers Act.

However, the small number of rate cases (fewer than 50 through 2015) that have been filed at the Surface Transportation Board (STB) since this industry regulatory body was established in 1996 has caused some industry observers to question whether the rate relief provisions of the Staggers Act have been working in a manner that is consistent with the law's dual goals of allowing railroads to achieve revenue adequacy and also protecting shippers from excessive rates. The rate relief process—which was

[1] The Regional Rail Reorganization Act of 1973 (3R Act) provided funding to railroads that were bankrupt and authorized the creation of Conrail. At this time, seven large railroads in the Northeast and Midwest were in bankruptcy. The Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) provided additional funding to these railroads but also introduced the concept of market dominance and established a zone of rate flexibility.

[2] See Meyer and Morton (1975), Wilson (1994), and others for more discussion.

[3] There have been many studies of the effects of these actions on industry performance. See Boyer (1987), Burton (1993), MacDonald (1989), MacDonald and Cavalluzzo (1996), McFarland (1989), Winston (1993, 1998), Winston et al. (1990), Wilson (1994, 1997).

put in place by the Interstate Commerce Commission (ICC) and continued by the STB—has come under regular criticism for its lack of transparency, inconsistency with economic theory, high cost of access, and inappropriateness for some shippers: particularly those with small shipment volumes and small rate-relief claims.

The STB's Uniform Rail Costing System (URCS) is a crucial input to this rate-relief process. It is used to screen rates for eligibility to be challenged. Staggers requires the rate to exceed 180 % of a shipment's URCS "variable cost" in order to establish eligibility. URCS is also used in STB proceedings to assess the reasonableness of the challenged rate if market dominance is found, and in some cases, even to set the value of the regulated rate.[4] Because of its central role in the STB rate relief process, URCS should provide an economically meaningful measure of shipment-level costs on which a profit-maximizing railroad would base its pricing and operating decisions. Otherwise, which shipments receive rate relief and the level that is set for a reasonable rate may simply be the result of an arbitrary cost allocation process, which would imply an arbitrary process for receiving rate relief.

The purpose of this paper is to provide an assessment of the validity of using URCS in the STB's rate relief process. We first review the STB's regulatory mandate under the Staggers Act, emphasizing the critical role played by URCS. We then describe the details of the URCS methodology in order to demonstrate that it is an administrative cost-allocation procedure that is used to assign fractions of accounting cost categories to specific shipments. Any change in these cost allocation rules that are used to compute the URCS "variable cost" of a shipment changes the value of this measure, which would affect the shipment-level revenue-to-variable-cost ratio (R/VC) and, therefore, change which rail shipments violate the STB's initial market dominance screen.

We then assess whether the URCS "variable cost" of a shipment provides an economically meaningful measure of the increase in the railroad's costs that are caused by providing that shipment. To accomplish this, we introduce the economic theory of costing in multiproduct industries to demonstrate how cost concepts that affect the pricing and operating decisions of a profit-maximizing railroad are determined. This discussion demonstrates that the URCS "variable cost" can differ significantly and unpredictably from the incremental cost of a shipment or the marginal cost of moving one more ton of the good that is being shipped. These two cost concepts are relevant to the pricing and operating decision of a profit-maximizing railroad.

We also demonstrate that even if the STB knew a railroad's shipment-level multiproduct cost function and was able to compute an accurate measure of the incremental cost of a shipment or the marginal cost of shipping an additional ton, this information would be of limited use in determining the reasonableness of the rate that is charged for a shipment. Railroads provide many shipments using the same rail line, yards, and even the same train. This implies the existence of significant economies of scope and scale in the provision of rail services. The presence of substantial joint and common costs[5] that give rise to these economies of

[4] The various STB regulatory processes for obtaining rate relief are described in Sect. 2.

[5] Joint costs relate to costs that are incurred when the production of one good necessarily results in the production of another good. Common costs refer to costs that are shared across multiple outputs.

scope and scale requires the railroad to price some traffic above its incremental cost or marginal cost of an additional ton shipped in order to achieve sufficient firm-wide revenues to recover total production costs.

Consequently, even complete knowledge of the railroad's multiproduct cost function would still leave the regulator with the challenging task of setting the maximum allowable markup over the marginal cost of the additional ton that is shipped for each product. Accordingly, the problem of determining an excessive price for a shipment is isomorphic to the problem of determining an excessive mark-up over the marginal cost of a shipment.

For all of these reasons, we argue that the URCS methodology should be abandoned and that an alternative approach to protecting captive shippers from excessive rates should be developed in the post-Staggers Act regime where a significant fraction of shipments is exempt from rate relief and many shipments move under confidential negotiated rates. We recommend an approach that builds on the price benchmark concept that was proposed in the recent National Academies of Sciences/Transportation Research Board Report (2015).

The remainder of the paper proceeds as follows: The next section describes the current STB methodology for fulfilling its Staggers Act regulatory mandate. Section 3 presents our analysis of the validity of the URCS methodology for computing the "variable cost" of a shipment. Shipment cost concepts that are based on the economic theory of multiproduct production are then derived and contrasted with the URCS "variable cost" of a shipment. This section also describes how shipment-level cost concepts that are grounded in economic theory are used by profit-maximizing railroads to set shipment prices and make operating decisions.

Section 4 presents empirical evidence that demonstrates that the URCS "variable cost" of a shipment fails several tests of its appropriateness for use in setting shipment prices and making rail operating decisions. Section 5 demonstrates that even the best possible economic model for how railroad costs are incurred would be of limited use in determining a reasonable regulated shipment price without detailed knowledge of the demand functions that the railroad faces for all rail services.

Section 6 describes what cost information should be collected by the STB to meet its Staggers Act regulatory mandate in an industry with a significant fraction of shipments that are exempt from the rate relief process. The final section of the paper summarizes our findings that the URCS methodology does not yield an economically valid measure of the cost of a shipment and concludes that its use should be abandoned in the rate relief process.

2 Staggers Act Regulatory Mandate and URCS

This section describes the regulatory mandate of the STB as determined by the Staggers Act and other railroad legislation passed around the same time. This discussion focuses on how the URCS methodology is used in the process to determine market dominance of a shipper and how URCS "variable costs" are used to determine the reasonableness of a rate.

2.1 The Staggers Rail Act Regulatory Mandate

The goal of the Staggers Rail Act of 1980 was "…to provide for the restoration, maintenance, and improvement of the physical facilities and financial stability of the rail system of the United States." (49 USC 10101a). The Staggers Act emphasized the need for an efficient transportation system wherein rail carriers earn adequate revenues (49 USC 10101a) to recover their total cost. To this end, the STB is required to undertake periodic analyses of whether the railroads are earning adequate revenues to maintain their long-term financial viability and able to continue to invest to serve an ever-changing demand for rail transportation services. This process is typically referred to as the annual revenue adequacy determination.

From a regulatory standpoint, rail shipments move under three major rate regimes: The first are shipments that are automatically exempt from regulation because the STB has determined that the railroad faces adequate competition for the rail service from trucks. The rates that are charged for these shipments cannot be challenged. The second are shipments that move under negotiated contract rates, which are exempt from rate relief and regulatory oversight for the life of the contract. The third are shipments that have not been exempted and that are transported using posted tariff rates. These shipments, which consist mainly of bulk goods that cannot be competitively moved by truck, can be challenged if they qualify under the law's definition of market dominance.

2.2 The Use of URCS to Determine Market Dominance

For the reasonableness of a rate to be considered, the movement must first be found to be "market dominant". Currently, market dominance requires that the rate exceeds 180 % of the URCS "variable cost" (VC) of that movement computed from the URCS model described in Sect. 3.1 and there is an absence of effective competition. If the STB finds that the revenue the railroad receives from the shipment does not exceed 180 % of the URCS "variable cost" of the shipment, the agency does not have jurisdiction to review the rate; and as pointed out by Eaton and Center (1985) and Wilson (1996), this finding is not rebuttable.

Only if the R/VC ratio is greater than the 180 % threshold can the shipper challenge the rate by presenting evidence to the STB that is intended to demonstrate a lack of effective competition in the market. Eligibility for rate relief is established only after the STB conducts a more detailed market review and finds a lack of effective competition. Until the late 1990s, the evaluation of effective competition was a qualitative evaluation of intra-modal, inter-modal, product, and geographic competition in the market. In 1999, the STB eliminated the requirement that it consider product and geographic competition, which leaves only a qualitative evaluation of whether intra-modal or intermodal competition is present.[6]

[6] Market Dominance Determinations—Product and Geographic Competition, STB Ex Parte No. 627, July 1, 1999, available at http://www.stb.dot.gov/boundvolumes4.nsf/b466c97893ec3be08525680b006041bd/f317b26a2b7d098b85256ed900651244/$FILE/vol4-20.pdf.

Determining whether a railroad faces effective competition based on the presence of firms that the railroad loses business to can fall prey to the "cellophane fallacy" in competition analysis. In the US v. Du Pont de Nemours and Co. (1956) case, the Department of Justice claimed that Du Pont had a monopoly of cellophane. Du Pont claimed that it faced effective competition in a broader product market. However, one interpretation of these facts and the source of the "cellophane fallacy" is that Du Pont's elevated price for cellophane (which yielded it above-normal profits) caused these other products to compete with cellophane. Returning to the rail transportation industry, a railroad losing some sales to competitors on a route does not necessarily mean that it faces effective competition on that route.

2.3 The Use of URCS in Rate Reasonableness Determinations

Given a market dominance finding, reasonableness of the rate may be considered. The guidelines for a reasonable rate were issued in 1985 by the ICC in its Coal Rate Guidelines. These standards—the "constrained market pricing standards"—hold that captive shippers should not be required to pay more than necessary for the railroad to earn adequate revenues and should not pay for railroad inefficiencies nor for the costs of facilities and services from which the shippers derive no benefit.

Until the mid-1990s, rate reasonableness was considered under the Stand-Alone Cost (SAC) standard. In the mid-1990s, additional standards were introduced to make rate relief more accessible to small shippers. Currently, there are three different approaches that shippers can use to challenge a rate: (1) the Stand-Alone Cost (SAC); (2) the Simplified SAC; and (3) the Three Benchmark test. Each will be discussed in turn.

The SAC test seeks to determine the lowest cost at which a hypothetical, efficient carrier could provide the service under consideration. The hypothetical railroad—"Standalone Railroad" (SARR)—serves a subset of movements in the railroad's network and is "efficient" in the sense that it produces in a least cost manner. The subset of movements the SARR is assumed to serve includes the traffic under consideration, but may reflect other so-called "cross-over" traffic (i.e., traffic that runs on the same tracks) that an efficient railroad would serve. The total cost of the SARR (including an adequate return on investment) is then used to determine the maximum amount that the railroad can charge for the shipment under consideration.

A number of commentators have argued against the use of the SAC test in making a rate reasonableness determination. Pittman (2010) argues that the theoretical justification for the SAC test to yield a reasonable rate is built upon the assumption of a rail monopolist that is constrained to zero economic profits while operating in a contestable market with pricing that is designed to deter inefficient entry. Pittman (2010) notes that under Staggers railroads are not constrained to earn zero profits, and the markets they compete in are not contestable (due to the presence of enormous sunk costs and substantial entry/exit barriers). Indeed, as Faulhaber (2014) states: "the use of Stand-Alone Cost in railway rate regulation is so far from the models in which it was originally developed as to be unrecognizable." He goes on to describe the theoretical underpinning of the model (a monopoly with all of its prices regulated and with a zero profit constraint) and argues that the realities of the railroad market do not fit the underlying assumptions of the model.

Pittman (2010) also discusses the many practical challenges that are associated with implementing the SAC test. He details the substantial evidentiary burden and the financial and time costs that are associated with this procedure. He points to STB estimates that the costs to a shipper to bring a SAC test case are close to $5 million. He argues for its retirement and replacement with a more straightforward and transparent process.

The Simplified-SAC is an alternative procedure that is designed to retain, at least, some of the logic of SAC. It was adopted by the STB in response to a Congressional mandate that was contained in the Interstate Commerce Committee Termination Act of 1995 that ordered the newly created STB to develop expedited procedures for resolving disputes that could be used by more shippers that were unable to use the SAC standard. Under this procedure, the analysis focuses on the replacement cost of existing facilities that are used to serve the shipper and the return on investment that the SARR would require to replicate the facilities. Reasonableness is then determined from the costs of the SARR that provides the traffic.

This procedure is designed to involve less time and money to compute the SAC value for the hypothetical railroad. Until 2013, the Simplified-SAC had a limit to potential financial recovery for the shipper from the railroad of $5 million; but in 2013 the limit was removed in STB Docket 715.

The Three-Benchmark approach is another "simplified" approach that is intended for shippers with smaller claims. Under this approach, the reasonableness of the rate is determined by comparing it to three rate benchmarks. These benchmarks are expressed in terms of the ratio of revenue to the URCS "variable cost". The benchmarks are: (1) the average markup above the URCS "variable costs" that a carrier would need to charge all of its potentially captive traffic (those with R/VC ratios greater than 180 %) to recover all of its non-variable costs; (2) the average markup above URCS "variable costs" that a carrier receives on its captive traffic (R/VC greater than 180 %); and (3) the average markup that is assessed on other potentially captive traffic that involves the same or a similar commodity that moves a similar distance. Again, the potential overcharge recovery from the railroad by the shipper is limited, in this case, to $1 million. The maximum overcharge recovery was changed in 2013 to $4 million.

The cost and administrative burden of undertaking rate reasonableness cases has led to a limited number of them being filed, particularly by shippers that move a small amount of volume on an annual basis. These shippers are also more likely to use the Three Benchmark Test, which relies on URCS "variable cost" of a shipment. Consequently, if (as we demonstrate in the next two sections) the URCS "variable cost" is not an economically meaningful measure of the cost of a shipment, small shippers are more likely to receive inappropriate or ineffective rate relief because of the use of the URCS "variable cost" in this regulatory process.

Since the STB was established in 1996, there have been a total of 51 cases filed as of January 15, 2015: an average of slightly more than 2.5 cases per year. Forty-eight have been decided, and three are still pending. Of the 48 decided, 31 involved coal movements, followed by chemical movements with 15 cases, and grain and minerals each have a single case. This mix of cases is consistent with the logic that only shippers that move a substantial volume on an annual basis are likely to obtain rate relief that justifies the expense of the STB process.

Of the 48 resolved cases, rates were judged using the SAC test 34 times, the Simplified-SAC test five times, and the Three-Benchmark test five times; in four cases the parties agreed to use an alternative method.[7] Of the 31 coal cases, 27 were judged using the SAC test, and four on a stipulated R/VC basis: The parties agreed to use a revenue-to-URCS "variable cost" ratio at the 180 % level in lieu of using the SAC. Of the 15 chemicals cases, the SAC, Simplified-SAC, and Three-Benchmark were each used 5 times. SAC was used for both the grain and minerals cases. Most of the cases (25 out of 48) were settled. Of the remaining cases, rates were deemed to be "reasonable" in ten cases and "unreasonable" in 11, and two cases were withdrawn. The unreasonable rate findings applied to chemicals one time, coal nine times, and minerals one time.

If we assume that railroads maximize profits in setting rates and that they serve some routes that may not have effective competition from other railroads or other modes of transportation, the small number of rate relief cases that have been filed in the almost 20 years that the STB has been in existence suggests that the current approach to protecting captive shippers from excessive rates could be improved. For the reasons that are discussed in the following two sections, an important step towards providing a lower-cost and more transparent approach to rate relief is to eliminate the use of the URCS in this process.

3 The Arbitrary Nature of URCS "Variable Costs"

This section details why the URCS measure of the "variable cost" of a shipment is not a cost measure that a profit-maximizing railroad would use to make pricing and operating decisions. We first describe the accounting cost allocation procedure that is used to compute the URCS "variable costs" of a shipment. We then use the economic theory of multiproduct production to derive two economically meaningful measures of the costs of a shipment: (1) the marginal cost of shipping an additional ton; and (2) the incremental cost of a shipment of q tons. We then describe how each of these measures can be used by a profit-maximizing railroad to make pricing and operating decisions.

3.1 Railroad Costing and URCS

URCS was adopted in 1989 as the ICC's general costing program. It replaced Rail Form A, which was introduced in 1939 and remained in effect until it was replaced by URCS. The impetus for URCS came from the 4R Act, wherein the ICC was directed to provide a more accurate costing system. Over the next 12 years, the Railroad Accounting Principles Board (RAPB) was established to provide guidance to the ICC and to recommend appropriate costing methods. Following the RAPB

[7] http://www.stb.dot.gov/stb/industry/Rate_Cases.htm.

recommendations, the ICC revised the accounting system, and between 1980 and 1989 developed a new costing model, which became URCS.

URCS provides estimates of what the STB calls the "variable cost" of a generic type of shipment, based on a vector of observable shipment characteristics. We put quotes around variable cost when referring to this magnitude that is produced by URCS, because as will be discussed below, URCS is a methodology for allocating railroad costs to a generic shipment type, rather than a methodology for estimating the increase in the railroad's costs that are caused by making a specific shipment; that is, a priced unit of traffic that consists of a given quantity of a commodity that is being shipped from a given origin to a given destination.

The computation of the URCS "variable cost" takes place in three distinct phases: In phase I, massive amounts of raw data are compiled from railroads, the Association of American Railroads, the Carload Waybill Sample, and special studies (some of which date to the 1930s). As noted in ICC (1982, p. 2-1), "a distinguishing characteristic of URCS is the large amount of data required to develop railroad unit costs." The data are audited by the STB staff and form the foundation for the URCS Master File (UMF). These raw data are used to define the costs that are associated with 15 different railroad accounting cost categories for a variety output and capacity variables.[8]

The 15 different activities are listed in Table 1, along with eight output variables (the vector q) and six capacity or size variables (the capacity measure S) that are associated with these accounting cost categories. The process that is used to allocate items into the 15 accounting cost categories varies from extremely complex to relatively simple. For example, expenditures on maintenance of way and structures involve many inputs (several kinds of labor, materials, and administrative support), while running fuel includes gallons of fuel and the costs of the equipment and the labor that are used in the acquisition, storage, and transportation of the fuel (Westbrook (1988)). These groups of activities and the allocation of both fixed and variable costs into the groups are based on the similarity of the railroad activities, judgments regarding the "relatedness" of accounts, and generally accepted railroad accounting practices (ICC, 1982).

In Phase II, the calculation of the URCS "variable cost" of a shipment is relatively straightforward given this information. As Rhodes and Westbrook (1986) note, "In the URCS, variable costs for specific freight movements are calculated as weighted averages of total costs from individual cost categories that comport with cost categories defined in railroad accounting practices" (p. 290). This description clearly indicates that URCS is a methodology for allocating rail costs to individual shipments rather than a method for measuring the increase in the railroad's costs caused by a shipment.

In terms of the notation in Rhodes and Westbrook (1986), the URCS "variable cost" of a rail shipment of quantity q is equal to:

[8] As noted in STB (2010, p. 5), 78 % of total expenses are allocated to these groups. The remaining 22 % are assigned "default variability factors" based on prior judgments by the regulatory authority. For example, the return on road property investment and on capital expenditures are each assumed to be 50 % variable.

Table 1 UCRS activities

Activity	Output	Capacity
Running track maintenance	GTM(C)	MR
Track maintenance overhead	GTM(C)	MR
Running crew wages	TM, TH(W)	MR
Transportation overhead expenses	TM	MR
Transportation fuel expenses	GTM(C), LMR, TH(W)	MR
Road locomotive service and repair and overhead	GTM(C), LMR	MR
Road train inspection	CM	MR
Clearing wrecks	TM	MR
Switching maintenance and overhead	TH(S)	ST
Yard operations	TH(Y)	Y(ST)
Switching crew wages	TH(Y)	Y(ST)
Yard locomotive repairs	TH(Y)	Y(ST)
General and administrative	GTM(C)	MR
Freight car repair expenses, net	CM(PD)	MR
Freight car repair expenses, overhead	CM(PD)	MR

The output variables are: CLOR, carloads originated and received; CM, car-miles, all trains; GTM(C), gross ton-miles (cars, contents, cabooses); LMR, locomotive unit-miles, road service; TH(S), train hours, total switching; TH(W), train hours, way switching; TH(Y), train hours, yard switching; TM, train miles, running

The capacity (size) variables are: CM(PD), car-miles, railroad owned and leased, loaded and empty; MR, miles of road, total; ST, miles of track, switching; T, miles of track total; T(R), miles of track, running; Y(ST), miles of track

$$\mathrm{VC(q) = R(q;1)C(q;1) + R(q;2)C(q;2) + \cdots + R(q;K)C(q;K)}, \tag{1}$$

where C(q; k) is the observed total cost of the kth accounting cost category for shipment quantity vector q and R(q; k) is the unobserved weight (also called the *variability ratio*) that gives the fraction of the total cost of the kth accounting cost category that is allocated to shipment quantity vector q. Econometric methods that are described in more detail below are applied to each accounting cost category and output quantity measure to construct estimates of R(q; k).[9]

The total cost of each accounting cost category is assumed to take the additively separable form:

$$\mathrm{C(q;k) = F(k) + V(q;k)}, \tag{2}$$

where F(k) is the fixed cost of the kth category and V(q; k) is the variable cost of the kth category. The variable q is the level of the output variable or vector of the output variables that are listed in Table 1 associated with the kth accounting cost category.

[9] The URCS variable cost is additively separable across accounting activities (which implies that there is no substitutability in input costs between the activities). As will be shown in Eq. (6) below, the regressions that are run to operationalize these concepts are based on linear functional forms. As noted by Wilson and Bitzan (2003), each of these assumptions is unlikely to be consistent with how railroads incur costs.

The fixed cost of the kth category does not depend on the value of q, although both the variable cost and total cost of the kth category depend on q.

In terms of the elements of Eq. (2), the variability ratios or weights in Eq. (1) can be written as:

$$R(q;k) = V(q;k)/[F(k) + V(q;k)]. \tag{3}$$

Note that this activity-level cost-allocation factor is bounded between zero and one and is monotonically increasing in q, if V(q; k) is monotone in q. If railroads choose inputs to minimize the variable cost of supplying the vector of output q and are price-takers in input markets, then V(q; k) should be monotone in q.

To operationalize this model with the use of railroad accounting cost category data, the following functional form is assumed for Eq. (2):

$$C(q;k) = \alpha_k S_k + \sum_{m=1}^{M} \beta_{mk} q_{mk}, \tag{4}$$

where S_k is a measure of railroad capacity appropriate to the kth category; $(q_1, q_2, \ldots, q_M)'$ is the vector of railroad output variables for cost category k; and α_k and $\beta_{1k}, \beta_{2k}, \ldots, \beta_{Mk}$ are parameters to be estimated for accounting cost category k. As Rhodes and Westbrook (1986) note, the term $\alpha_k S_k$ represents F(k), and $\sum_{m=1}^{M} \beta_{mk} q_m$ represents V(q; k). This implies the following expression for the variability ratio for accounting cost activity k given in Eq. (3):

$$R(q;k) = \frac{\sum_{m=1}^{M} \beta_{mk} q_m}{\alpha_k S_k + \sum_{m=1}^{M} \beta_{mk} q_m}. \tag{5}$$

The URCS methodology estimates the parameters of Eq. (4) with the use of a panel data set of railroads over time. Let $C(q;k)_{jt}$ equal the total cost of the kth accounting cost category for railroad j during time period t, S_{jt} be the capacity of railroad j during time period t, and q_{mjt} be the value of output measure m for railroad j during time period t for the kth accounting cost category. The following ordinary least squares (OLS) regression is performed to recover estimates of and α_k and $\beta_{1k}, \beta_{2k}, \ldots, \beta_{Mk}$:

$$C(q;k)_{jt} = \alpha_k S_{jt} + \sum_{m=1}^{M} \beta_{mk} q_{mjt} + \varepsilon_{jt} \tag{6}$$

where the ε_{jt} ($j = 1, 2, \ldots, N$ and $t = 1, 2, \ldots, T$) are assumed to be mean zero, constant variance, uncorrelated random variables.

The final step in the process of estimating the cost allocation factors that are used to assign the share of total accounting category cost k to a specific shipment is the point of evaluation of the cost allocation factor. Let a_k and $b_{1k}, b_{2k}, \ldots, b_{Mk}$ denote the OLS estimates of α_k and $\beta_{1k}, \beta_{2k}, \ldots, \beta_{Mk}$; then

$$R^e(k, q^*) = \frac{\sum_{m=1}^{M} b_{mk} q_m^*}{a_k S^* + \sum_{m=1}^{M} b_{mk} q_m^*} \tag{7}$$

is the estimated variability ratio evaluated at S* and q*. As Rhodes and Westbrook (1986) note, for some cost categories S* and q* are set equal to sample means across railroads for each year. For other accounting categories S* and q* are "annualized values" that are computed with the use of moving averages of these variables over 3–5 years. The use of variability ratios for each accounting cost category for each year that do not depend on the specific values for S and q for the railroad and/or year under consideration further emphasizes the fact that the URCS "variable cost" of a shipment is determined from a procedure for allocating total accounting category costs to individual shipments, rather than from a methodology that estimates the increase in the railroad's total cost of production that is caused by that shipment.

Phase III of the URCS methodology uses these estimated weights or variability ratios to produce the "variable cost" of a given shipment, based on user inputs that consist of a commodity identifier, number and types of cars, the carrier, and the length of haul with the use of the associated values of $C(q; k)$, $k = 1, 2, \ldots, M$.

3.2 The Incremental Cost of a Shipment; and the Marginal Cost of a Ton Shipped

This section uses the economic theory of multiproduct production to derive a multiproduct cost function; and from this we derive two measures of the increase in production costs that are caused by the railroad that provides a specific shipment: (1) the incremental cost of a shipment of q tons; and (2) the marginal cost of shipping an additional ton. We then demonstrate that these two cost concepts place lower bounds on components of the revenues that a profit-maximizing railroad will require to move a shipment.[10]

The key distinction between variable versus fixed costs is that the variable cost of a specific activity can be causally related to that activity, whereas the fixed costs are unrelated to the existence or level of that activity. In the single product context, the variable cost of output level q is the short-run reduction in the firm's total cost of production as result of reducing its output from q to zero. If $C(q)$ is a function that provides the total cost of producing output q, then $VC(q) = C(q) - C(0^+)$, where 0^+ denotes that fact although the output level is zero, all fixed costs have been incurred. The marginal cost at output level q is the change in the total cost of production at output level q that is caused by a one-unit change in output q. Mathematically, it is equal to the derivative of the total cost function $C(q)$ at output level q: $dC(q)/dq$. The variable cost of any output level q and the marginal cost function are related by the following integral equation: $VC(q) = \int_{0^+}^{q} \frac{dC(s)}{ds} ds$. This implies that the variable cost of output q is the area under the marginal cost curve—$MC(s) = dC(s)/ds$—up to output level q. This relationship between these two cost concepts emphasizes the causal nature of the marginal cost at output level q and variable cost of output level q.

[10] Although Rhodes and Westbrook (1986, p. 291) criticize several of the assumptions that are implicit in the URCS methodology, their primary focus is the validity of the econometric methods that are employed to estimate the variability ratios that are used to compute the cost allocation factors that apportion shares of each accounting category total costs to individual shipments. They do not examine whether the URCS methodology yields an economically meaningful measure of the cost of a shipment.

Versions of the above results extend to the case of a multiproduct firm that produces M distinct products. Let $C(q_1, q_2, \ldots, q_M)$ equal total cost to the firm of producing the vector of outputs $(q_1, q_2, \ldots, q_M)$. For the case of a railroad, each q_i could equal the tons of a specific product that is shipped between an origin and destination pair. Consequently, for the case of a railroad, M (the number of outputs) could be extremely large.

The analogous concept to the variable cost in the single product context is the incremental cost of output q_i. It is equal to the difference between the firm's total cost of production at the vector of outputs $(q_1, q_2, \ldots, q_M)$ and the vector of outputs that set the output of product i equal to zero, $(q_1, q_2, \ldots, q_{i-1}, 0, q_{i+1}, \ldots, q_M)$. The incremental cost of product q_i given Q_{-I}, $IC(q_i|Q_{-i}) = C(q_1, q_2, \ldots, q_{i-1}, q_i, q_{i+1}, \ldots, q_M) - C(q_1, q_2, \ldots, q_{i-1}, 0, q_{i+1}, \ldots, q_M)$, where $Q_{-i} = (q_1, q_2, \ldots, q_{i-1}, q_{i+1}, \ldots, q_M)$ the vector of $M - 1$ output levels for all other products besides product i.

Note that the incremental cost of q_i depends on the output level of all other products, as well as the output of product i.[11] The incremental cost of q_i then can change depending on the value of Q_{-i} because of the common costs that are associated with the production of the elements of Q_{-i} and product i. There are likely to be substantial common costs for a railroad that provides rail shipments for different products and different origin and destination pairs. Thus, the incremental cost of q_i is likely to be smaller the larger are the number and size of individual elements of Q_{-i}, which reflects the fact that there are significant economics of scope in the provision of rail shipments both across commodities and different origin–destination pairs.

The marginal cost at q_i is the increase in the total cost of production associated with providing one more unit of product i given the value of Q_{-i}. Mathematically, the marginal cost of q_i is equal to the partial derivative of $C(q_1, q_2, \ldots, q_M)$ with respect to q_i. Define $MC(q_i|Q_{-i}) = \frac{\partial C(q_1, q_2, \ldots, q_M)}{\partial q_i}$. By the same logic as described above

$$IC(q_i|Q_{-i}) = \int_0^{q_i} MC(s|Q_{-i})ds = \int_0^{q_i} \frac{\partial C(q_1, q_2, \ldots, q_{i-1}, s, q_{i+1}, .., q_M)}{\partial q_i} ds, \quad (8)$$

which implies that the area under the marginal cost function for product i up to output level q_i given the value of Q_{-i} is equal to incremental cost of q_i given Q_{-i}.

It is worth noting that both the incremental cost and marginal cost for shipments along an origin and destination pair can rise rapidly in the quantity shipped when rail networks become congested because of high volumes of traffic relative to the capacity of the route. For example, immediately following the merger of Southern

[11] For the case of a single railroad that hauls two commodities, products 1 and 2, over the same rail line that connects an origin and a destination, the multiproduct cost function is $C(q_1, q_2)$. The incremental cost of the firm that ships q_1 given q_2—$IC(q_1|q_2)$—is equal to $(C(q_1, q_2) - C(0, q_2))$, which the difference between the cost of producing q_1 and q_2 and the cost of producing just q_2.

Pacific (SP) and Union Pacific (UP) in late 1997, significant congestion arose along a number of routes in the former SP network.[12]

It is important to emphasize that these properties of a multiproduct cost function do not rely on the assumption that the firm chooses its inputs in a cost-minimizing fashion, only that firm has a stable production plan for choosing the quantity of each input that is used to produce each output vector given the prices that it pays for these inputs.[13] We illustrate this finding and discuss its implications in the appendix.

3.3 URCS "Variable Costs" Versus the Incremental Cost of a Shipment

The URCS measure of the "variable cost" of a shipment does not in general yield a causal measure of the cost of a shipment. Specifically, it cannot be derived as the area below marginal cost function for product i, up to the level of output of product i. As shown in the previous section, the URCS variable cost of a shipment allocates the total accounting category level costs using fixed variability ratios for each accounting cost category. Consequently, the URCS "variable cost" of a shipment is not equal to the increase in the railroad's total cost of production that is caused by providing that shipment. It is therefore not surprising that the URCS "variable cost" of a shipment frequently exceeds the revenue that a railroad charges for that shipment as will be shown later in Sect. 4.

In contrast, a railroad that sets the price for the shipment, p_i, so that the revenue earned is less than incremental cost of the shipment is clearly irrational.[14] The incremental cost of q_i is the increase in the railroad's total cost that is caused by providing q_i, and p_iq_i is the revenue that is earned. Therefore, the firm loses $(p_iq_i - IC(q_i|Q_{-i}))$ from providing this shipment. Consequently, the railroad would be better off not providing this shipment if it earns only revenue p_iq_i from doing so. It would also be irrational for a the railroad to set the price per-ton for a given origin–destination pair at a level that is less than that marginal cost of moving an additional ton, $\frac{\partial C(q_1,q_2,\ldots,q_M)}{\partial q_i}$, because doing so would imply that the railroad loses money in the movement of that additional ton. For this reason, we would expect a railroad to set the revenue for shipment above the incremental cost of providing that shipment and to set the marginal price for an additional ton at a level that is above the marginal cost of a ton.

[12] For more on this issue, see Nolte, Carl and Howe, Kenneth, "Transcontinental Rail Gridlock: Merging of SP, UP tracks creates a train bottleneck," *San Francisco Chronicle*, October 11, 1997.

[13] The assumption of cost minimization is not needed to compute these causal cost concepts. As long as a railroad has a stable production plan in the sense described in the appendix, incremental and marginal cost are economically meaningful for determining prices that recover shipment costs with railroads that employ inefficient modes of production.

[14] While it is possible that pricing below incremental costs may reflect price wars, signals of toughness with rivals, or even predatory pricing, the routes, frequency, and time periods when this occurs seems inconsistent these explanations.

4 Examining the Empirical Content of URCS Cost Measures

This section presents several lines of empirical evidence to support the conclusion that the URCS methodology does not produce an economically meaningful measure of the cost of a shipment that a rational railroad would use to make pricing and operating decisions. First, we show that across all product categories and for both years that we examine a non-trivial fraction of shipments in the STB Waybill Sample have revenue (R) to URCS variable cost (VC) ratios that are less than one. This result implies that if the URCS "variable cost" is a valid measure of the increase in the railroad's cost from providing the shipment, the railroad would lose money on these shipments, and their provision is clearly inconsistent with rational behavior by the railroad.

We then perform two counterfactual URCS variable cost computations that demonstrate that plausible re-allocations of non-causal cost components (depreciation, return on investment, and the sum of these two components) that are consistent with the URCS methodology yield substantially different values for the URCS variable cost of a shipment. The new URCS "variable costs" that result from these re-allocations change which shipments have revenues that exceed the 180 % of the URCS "variable cost" threshold and are therefore eligible for regulatory scrutiny. These results demonstrate the arbitrary nature of regulatory rate relief that results from a regulatory process that is based on the URCS cost allocation mechanism.

4.1 Frequency of "Irrational" Pricing Implied by URCS Costs

We examine the frequency that "irrational" pricing occurs for the URCS "variable cost" of a shipment using data from the STB's 1 % Waybill Sample.[15] We consider four broad categories of products that were shipped in 2006 and 2013: (1) farm products; (2) chemical products; (3) coal; and (4) petroleum products.[16] For each of these product categories and for both years, we first compile an estimate of the population distribution of the ratio of the shipment revenues to the URCS "variable cost" (R/VC) with the use of the expansion factors from the Waybill Sample data that give the representativeness of each shipment in the Waybill Sample in the annual population of shipments for farm products, chemicals, coal, and petroleum for 2006 and 2013.

Figures 1 and 2 plot the average revenue per ton-mile and the URCS "variable cost" per ton-mile for individual shipments in each commodity category for the

[15] The Carload Waybill Sample is available annually. It is a stratified random sample of waybills and contains shipment-specific information that allows prices and shipment characteristics to be identified along with the URCS "variable cost" of the shipment. More information is available from http://stb.gov/stb/industry/econ_waybill.html.

[16] Each of these product categories are identified by Standardized Transportation Commodity Codes (STCC). The product categories and associated STCC products included in each category are: (1) farm products (STCC2 = 1); (2) chemical products (STCC2 = 28); and (3) coal (STCC2 = 11). Petroleum products were defined by a collection of five digit commodities (13211, 291111, 29112, 29113, 29114, 29115, 29117, 29119, and 29121).

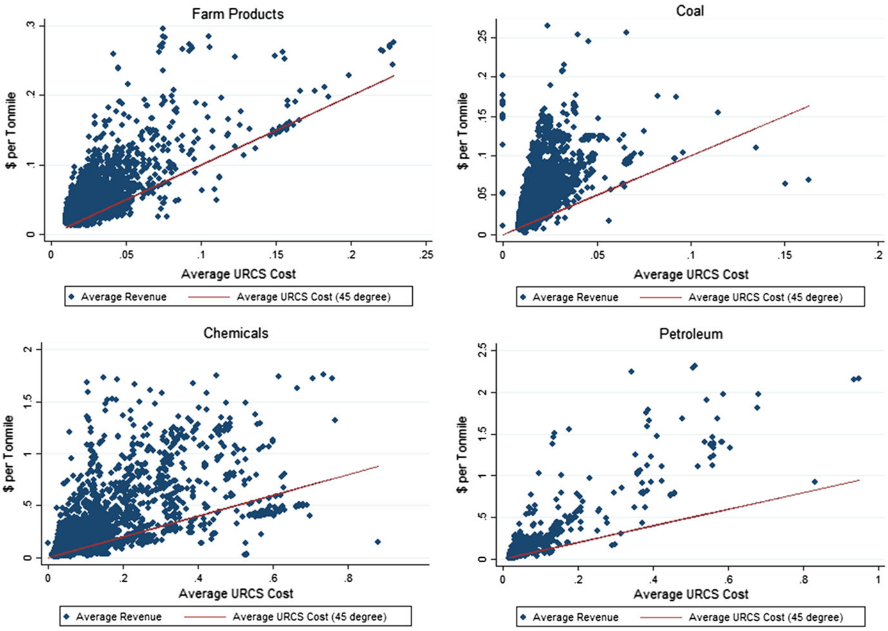

Fig. 1 ARTM versus average URCS cost per tonmile for the 2006 Waybill Sample

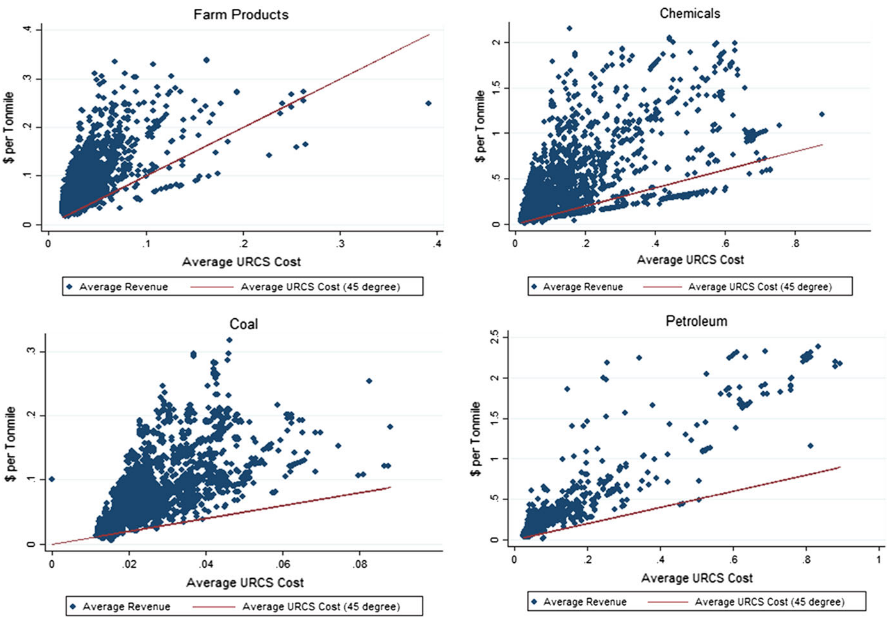

Fig. 2 ARTM versus average URCS cost per tonmile for the 2013 Waybill Sample

2006 and 2013 Waybill Samples along with 45-° line. Points that are above the 45° line represent R/VC ratios that are greater than one, while points that are below the line represent R/VC ratios that are less than one. In all of the figures, there are many shipments that lie below the line. This is particularly true for farm products and chemicals. Movements with R/VC values that are less than one are clearly inconsistent with rational decision-making, because it would imply that the railroad loses money by providing the shipment.

Table 2 presents the estimated population densities of the R/VC ratios for shipments from each commodity category for 2006 and 2013. To compute this density, each shipment in the Waybill Sample is assigned a weight that gives the estimated frequency that it occurs in the population of annual shipments. The second column of Table 2 contains the estimated R/VC population frequencies for 2006 that fall within the range of values that are in the first column, and the third column contains the similar estimated population frequencies for 2013.

In 2006, a significant portion of shipments have R/VC values that are less than 1.0 for all commodities. For farm products, chemicals, coal and petroleum, these percentages are 20.44, 15.41, 16.25, and 18.82, respectively. In 2013, the percentages are sizeable for all commodities but petroleum products. For farm products, chemicals, coal, and petroleum, these percentages are 8.32, 6.58, 4.47, and 0.39, respectively. In 2006, the estimated population percentage that R/VC exceeds the 1.80 is 18.49, 43.85, 48.57, and 41.35 for farm products, chemicals, coal, and petroleum, respectively. In 2013, the estimated population percentage that R/VC exceeds the 1.80 is 31.43, 61.77, 66.93, and 44.45 for farm products, chemicals, coal, and petroleum, respectively.

The significant frequency of the values of R/VC that are less than one for all commodities in 2006, and all but one product category, petroleum, in 2013, implies widespread “irrational” pricing by the railroads under the assumption that the URCS “variable cost” is an economically meaningful measure of the cost of a shipment. These results provide strong empirical evidence that the URCS variable cost of a shipment is not a cost measure that any rational railroad would use as a basis for pricing or operating decisions, because it is highly unlikely that a rational railroad manager would provide shipments that cost the railroad more to supply than it earns in revenues.

4.2 The Arbitrary Nature of Violations of the URCS R/VC Benchmark

The URCS program allocates portions of the accounting cost categories that are shown in Table 1 to individual shipments. Several of these accounting cost categories are clearly not affected by a railroad that provides an individual shipment.

The next step in our analysis involves inputting the characteristics of shipments from the 1 % Waybill Sample for 2006 and 2013 into the URCS program, and we compute all of the allocated cost components of the URCS “variable cost” of the shipment. We then evaluate the sensitivity of the R/VC ratio for a given vector of shipment characteristics to differences across railroads in how three non-casual cost components are included in the URCS variable cost of a shipment.

Table 2 Population distribution of REV/VC

Rev/VC	Farm Products		Chemicals	
	Probability 2006	Probability 2013	Probability 2006	Probability 2013
<1.0	20.44	8.32	15.41	6.58
1.0–1.2	18.02	8.39	9.91	3.52
1.2–1.4	19.38	20.02	10.95	7.51
1.4–1.6	13.29	16.86	10.61	10.02
1.6–1.8	10.38	14.99	9.26	10.58
1.8–2.0	7.45	10.88	9.81	10.68
2.0–2.2	3.57	6.83	7.65	8.41
2.2–2.4	2.4	4.29	5.85	7.54
2.4–2.6	1.65	2.94	4.41	6.78
2.6–2.8	1.23	2.16	3.44	4.77
2.8–3.0	0.65	1.57	2.46	3.43
>3.0	1.54	2.76	10.23	20.16
R/VC > 1.80 (180 %)	18.49	31.43	43.85	61.77
Rev/VC	Coal		Petroleum	
	Probability 2006	Probability 2013	Probability 2006	Probability 2013
<1.0	16.25	4.47	18.82	0.39
1.0–1.2	9.74	2.54	7.5	2.29
1.2–1.4	9.79	4.69	10.32	7.9
1.4–1.6	5.93	8.69	8.62	18.08
1.6–1.8	9.74	12.69	13.39	15.25
1.8–2.0	8.08	12.07	10.41	9.92
2.0–2.2	8.96	13.85	7.57	10.07
2.2–2.4	5.04	7.37	7.52	7.48
2.4–2.6	4.31	4.65	4.62	6.84
2.6–2.8	3.79	4.43	3.2	4.65
2.8–3.0	2.65	3.93	2.22	5.2
>3.0	15.74	20.63	5.81	0.29
R/VC > 1.80 (180 %)	48.57	66.93	41.35	44.45

All figures are weighted by the Waybill Sample expansion factors

The non-causal cost components that we consider are: (1) depreciation (Depr); (2) return on investment (ROI); and (3) the sum of these two cost components (Depr + ROI). We find substantial differences in the values of the R/VC ratio and in the categories of shipments that violate the R/VC < 1.80 threshold, depending on these arbitrary cost re-allocations. These findings further undermine the validity of the URCS "variable cost" as an economically meaningful measure of the cost of a shipment.

Our first analysis identifies shipments at the 10th, 20th, …, 90th percentiles of the average revenue per ton-mile distribution for each commodity group—farm products, chemicals, coal, and petroleum—for each year. The shipment-level characteristics that are available include the railroad that provided the shipment, the distance traveled, the commodity transported, the number of cars, the type of car, the weight per car, the segment type, car ownership, and whether it is a single, multiple, or unit train movement.

We then calculate the URCS "variable cost" components for each shipment[17] for each of the seven Class I carriers.[18] Specifically, for the 10th, …, 90th percentile shipments, we hold the shipment characteristics fixed across the seven railroads, changing only the identity of the railroad, and we re-compute the URCS "variable costs" for each of the nine shipments.

This procedure quantifies the differences across railroads in the R/VC ratios for the same vector of shipment characteristics and shipment revenue as a result of differences in how URCS allocates the same three non-casual accounting cost categories for each of the seven Class 1 railroads. If the URCS "variable cost" of shipment truly reflected an economically meaningful measure of the variable cost of a shipment, it is unlikely that the variable cost of a movement with the same observable characteristics would be significantly different for different railroads.

The second exercise replaces the non-causal URCS cost components for the actual shipment with those from a shipment with the same characteristics from one of the remaining six railroads with the smallest value of each of three non-causal cost components and largest value of each of the three non-causal cost components. This analysis investigates the extent to which violations of the R/VC $>$ 1.80 threshold could be primarily the result of differences in administratively determined cost allocation rules across railroads. It is difficult to argue that changes in cost allocation rules for the three non-causal cost components are the result of the railroad providing the shipment. They occur because of differences in how the URCS accounting cost allocation methodology that were described in Sect. 3.1 is applied to each railroad. Consequently, if the values of R/VC change significantly as result of this exercise, this is further evidence against the use of the URCS "variable cost" in the rate relief process.

4.2.1 Firm-Level Heterogeneity in URCS Costs Due to Non-casual Cost Allocations

For each of these nine percentile movements for each product category, we first calculate the URCS "variable cost" with the use of the observed shipment characteristics for each of the seven Class I railroads. We then recover from the URCS program the components of the URCS "variable cost" for that shipment that are unlikely to be caused by the railroad that provided that shipment (depreciation

[17] The program can be downloaded from the STB Website (http://www.stb.dot.gov/stb/industry/urcs.html), which also provides annual update files (from 2006 to 2013). Due to space constraints, we only report results for 2006 and 2013.

[18] The seven Class 1 railroads are: Burlington Northern and Santa Fe (BNSF); Norfolk Southern (NS); Union Pacific (UP); CSX Transportation (CSXT); Canadian National (CN); Canadian Pacific (CP); and Kansas City Southern (KCS). In the results, the identity of the railroads is not provided to retain confidentiality.

and returns on investment).[19] We then compute the URCS "variable cost" for each of the seven of the Class 1 railroads that subtracts out these non-causal cost components from the URCS "variable cost" measure for that railroad for a shipment with the same characteristics as the actual shipment. Then for each of the seven Class I railroads, we compute the ratio of the actual revenue for the shipment divided by these counterfactual URCS variable cost measures. We then repeat this same exercise for each 10th percentile in the distribution of shipments as determined by the average revenue per ton-mile.

Tables 3 and 4 contain the results for 2006 and 2013, respectively, but for the 50th percentile shipment only.[20] The railroad in the first column of each table is the railroad that actually provided the shipment. The railroad listed in the second column is the railroad that was used to compute the URCS "variable cost" of a shipment with the same observable characteristics as the actual shipment. The third column of the table gives the R/VC figure for a shipment with the same characteristics as the actual shipment using the URCS variable cost of the shipment for the simulated railroad in column 2. If the railroad number in the first column agrees with the railroad number in the second column, then the value of R/VC is the revenue to URCS "variable cost" ratio for the actual shipment.[21]

Tables 3 and 4 point to tremendous variation in URCS variable costs for the same shipment across railroads; and in some cases these differences have different regulatory implications. For example, the R/VC values range from 1.65 to 2.55 for farm products in 2006, and from 1.47 to 2.28 for coal in 2006. The URCS "variable cost" differences across railroads imply that some railroads that are potential market dominant and others are not market dominant for the same shipment characteristics and revenues. There are similar examples for 2013—especially for coal and for petroleum.

The values of Rev/(VC − Depr) in Tables 3 and 4 divide the actual revenue for the shipment by the URCS "variable cost" less the value of Depr for that shipment for the railroad listed in column 2. Subtracting Depr, which is clearly not a cost that is caused by a railroad that provides a specific shipment, increases the revenue to adjusted URCS variable cost ratio, which increases the likelihood of violations of the R/VC > 1.80 threshold. The values of Rev/(VC − ROI) subtract the ROI cost component for the railroad listed in column 2. Column 6 subtracts Depr + ROI

[19] The URCS program allows outputs that include the cost components. These cost components are provided in the user manual for the URCS program. In our case, we define depreciation as the sum of cost component outputs labeled numerically by the program as (605, 608, 615, 621, 624, 627, 630, 635, 638, 642, 645, 648, 651, 654, 657, 660, 663, 666, 669, 672, 675, 678, 681, 686, 690, 693) and return on investment costs (603, 606, 609, 616, 622, 625, 628, 631, 636, 639, 643, 646, 649, 652, 655, 658, 661, 664, 667, 670, 673, 676, 679, 682, 687, 691, 694).

[20] The other percentiles are available in the working paper version of this paper, which is available on RESEARCHGATE or the co-authors' webpages (http://pages.uoregon.edu/wwilson or www.stanford.edu/~wolak.

[21] We used railroad numbers instead of railroad names to preserve the confidentially of the revenue information in the Waybill Sample data. The railroad number in these tables denotes the same railroad across all tables.

Table 3 Revenue-to-variable-cost ratios: 2006

Actual RR	Simulated RR	Rev/VC	Rev/ (VC − Depr)	Rev/ (VC − ROI)	Rev/ (VC − Depr − ROI)
1	1	2.52	2.94	3.06	3.71
1	2	2.15	2.46	3.49	4.37
1	3	2.55	2.59	3.72	3.80
1	4	1.91	2.28	2.52	3.19
1	5	1.80	2.28	2.21	2.99
1	6	1.65	2.19	2.09	3.04
1	7	2.19	2.75	2.61	3.45
Chemicals					
7	1	0.68	0.71	0.74	0.78
7	2	0.88	0.92	1.12	1.18
7	3	0.54	0.57	0.59	0.63
7	4	0.65	0.68	0.74	0.77
7	5	1.04	1.11	1.09	1.16
7	6	0.72	0.77	0.82	0.88
7	7	0.56	0.59	0.62	0.66
Coal					
7	1	2.19	2.47	2.66	3.08
7	2	1.76	1.99	2.89	3.58
7	3	2.28	2.61	2.75	3.26
7	4	1.77	1.97	2.30	2.67
7	5	1.53	1.81	1.89	2.34
7	6	1.47	1.74	1.89	2.36
7	7	2.12	2.46	2.56	3.07
Petroleum					
7	1	1.39	1.49	1.56	1.68
7	2	1.60	1.72	2.20	2.45
7	3	1.28	1.38	1.42	1.56
7	4	1.29	1.38	1.51	1.63
7	5	1.65	1.85	1.87	2.12
7	6	1.19	1.31	1.39	1.55
7	7	1.22	1.32	1.38	1.52

from the URCS "variable cost" from the railroad listed in column 2. There are several cases where the R/VC of column 3 is less than 180 %, but greater than 180 % when these non-causal factors are subtracted both for 2006 and 2013 (columns 4–6).

Other percentiles of the distribution of average revenue per ton-mile for a single railroad movement yield similar conclusions, especially for some of the lower percentiles. For some railroads, the use of the URCS variable cost measure for that railroad implies that the railroad would make losses by providing the shipment. For

Table 4 Revenue-to-variable-cost ratios: 2013

Actual RR	Simulated RR	Rev/VC	Rev/(VC − Depr)	Rev/(VC − ROI)	Rev/(VC − Depr − ROI)
7	1	2.47	2.80	3.03	3.54
7	2	2.09	2.32	3.19	3.73
7	3	2.63	2.69	3.66	3.78
7	4	2.09	2.34	2.78	3.25
7	5	1.85	2.17	2.64	3.33
7	6	1.93	2.21	2.61	3.16
7	7	2.44	2.93	3.03	3.82
7	1	2.15	2.34	2.52	2.77
7	2	2.67	2.95	3.95	4.58
7	3	2.71	2.91	3.57	3.92
7	4	2.13	2.31	2.68	2.97
7	5	2.17	2.45	3.02	3.59
7	6	1.96	2.19	2.51	2.90
7	7	2.50	2.84	3.05	3.55
Coal					
4	1	2.22	2.48	2.75	3.17
4	2	1.86	2.07	2.84	3.36
4	3	2.29	2.49	3.13	3.52
4	4	1.85	2.05	2.48	2.85
4	5	1.63	1.87	2.43	3.00
4	6	1.68	1.96	2.31	2.86
4	7	2.37	2.77	3.04	3.74
1	1	1.73	1.86	2.00	2.17
1	2	2.23	2.43	3.15	3.56
1	3	2.25	2.40	2.92	3.17
1	4	1.75	1.88	2.14	2.34
1	5	2.01	2.25	2.75	3.24
1	6	1.71	1.88	2.13	2.42
1	7	2.00	2.23	2.40	2.74

modifications of the URCS “variable cost” that subtract Depr, ROI, or Depr + ROI, several railroads would violate the revenue to variable cost threshold of 1.8. The higher is the percentile of the distribution of average revenue per ton-mile, the more likely are the violations of the excessive rate threshold to occur as a result of subtracting out these railroad-specific non-casual cost allocations.

The results in these tables suggests that arbitrary changes in cost allocation rules for non-causal cost components could significantly change what shipments are subject to further regulatory scrutiny. Moreover, depending on how much of these non-causal costs are eliminated from the URCS “variable costs,” virtually any shipment could have a R/VC ratio that exceeds the 1.80 threshold.

Table 5 2006 R/VC by percentile movement and alternative definitions of URCS VC—railroad differences

Actual RR	Centile	Revenue/variable cost						
		Actual	Min-Depr	Max-Depr	Min-ROI	Max-ROI	Min-Depr and ROI	Max-Depr and ROI
Farm products								
1	10	1.02	1.02	0.95	1.03	0.85	1.03	0.80
4	20	1.05	1.06	1.00	1.13	0.95	1.13	0.91
1	30	2.06	2.37	1.67	2.06	1.62	2.37	1.37
6	40	1.08	1.14	1.08	1.17	1.01	1.25	1.01
1	50	2.52	2.89	2.04	2.52	1.98	2.89	1.67
1	60	1.23	1.34	1.06	1.23	1.08	1.34	0.94
7	70	2.46	3.03	2.20	2.48	2.03	3.06	1.85
4	80	1.59	1.59	1.51	1.68	1.44	1.69	1.38
6	90	2.00	2.08	2.00	2.20	1.84	2.30	1.84
Chemicals								
7	10	1.04	1.07	1.01	1.06	0.91	1.09	0.88
7	20	1.16	1.19	1.12	1.18	0.99	1.21	0.96
1	30	1.27	1.27	1.21	1.27	1.10	1.27	1.06
1	40	1.89	1.89	1.77	1.89	1.59	1.89	1.51
7	50	0.56	0.57	0.55	0.60	0.54	0.62	0.54
7	60	1.85	1.89	1.80	1.88	1.65	1.93	1.62
4	70	1.69	1.70	1.64	1.80	1.58	1.81	1.53
7	80	1.88	1.93	1.87	1.98	1.76	2.04	1.75
1	90	4.00	4.00	3.86	4.08	3.58	4.09	3.47
Coal								
1	10	0.89	0.89	0.79	0.89	0.67	0.89	0.62
1	20	0.97	0.97	0.77	0.99	0.71	0.99	0.60
1	30	1.12	1.12	0.89	1.14	0.82	1.14	0.69
7	40	1.47	1.51	1.35	1.48	1.12	1.53	1.06
7	50	2.12	2.18	1.95	2.14	1.63	2.21	1.53
7	60	2.71	2.79	2.50	2.74	2.09	2.82	1.96
6	70	2.53	2.74	2.53	2.83	2.28	3.11	2.28
6	80	2.88	3.37	2.63	3.31	2.53	4.00	2.34
4	90	3.13	3.16	3.01	3.45	2.84	3.48	2.74
Petroleum								
7	10	0.47	0.49	0.47	0.49	0.43	0.50	0.42
1	20	1.04	1.04	0.98	1.05	0.88	1.05	0.83
7	30	1.17	1.20	1.13	1.19	1.01	1.22	0.98
7	40	1.05	1.07	1.04	1.09	0.96	1.11	0.95
7	50	1.22	1.25	1.21	1.27	1.12	1.30	1.11
5	60	1.64	1.67	1.60	1.64	1.38	1.67	1.35
1	70	1.74	1.74	1.67	1.76	1.54	1.76	1.48

Table 5 continued

Actual RR	Centile	Revenue/variable cost						
		Actual	Min-Depr	Max-Depr	Min-ROI	Max-ROI	Min-Depr and ROI	Max-Depr and ROI
1	80	2.19	2.19	2.10	2.20	1.92	2.20	1.85
6	90	3.36	3.48	3.36	3.58	3.17	3.73	3.17

4.2.2 Firm-Level Heterogeneity in URCS Costs and Violations of the R/VC Threshold

The second analysis investigates how differences in the values of these non-causal costs across railroads affect the values of the R/VC for the railroad under consideration. For this exercise, the URCS variable cost is computed for the shipment at each 10th percentile of the shipment distribution, based on the average revenue per ton-mile for Class 1 railroads. We then subtract the value of Depr, ROI, or Depr + ROI from the URCS "variable cost" for that shipment and then add back the minimum value of this non-causal cost component or the maximum value of this cost component across the seven Class 1 railroads. This exercise asks whether using the values of these allocated cost components for other railroads for a shipment with the same characteristics would produce a significantly different value of R/VC.

Table 5 and 6 present the results of this exercise for each of the four commodity categories in 2006 and 2013, respectively. In this exercise, we represent all percentiles (10, …, 90). The railroad number in the first column of the table denotes the railroad that provided the shipment. The second column lists the percentile of the average revenue per ton-mile mile distribution. The third column lists the actual value of the R/VC for the shipment. The columns that are labeled min-X—for X = Depr, ROI, and Depr + ROI—compute a modified URCS "variable cost" by subtracting the actual value of the allocated cost X, and then adding back the minimum value of the allocated cost X across the seven Class I railroads. The column that is labeled max-X computes a modified URCS "variable cost" by subtracting the value of X and then adding back the maximum value of X across the seven Class 1 railroads. This table demonstrates that it is possible to achieve values of the R/VC that are less than one, between 1 and 1.8, greater than 1.8, and substantially larger than 1.8 by simply replacing the allocated cost component with the allocated cost component for a like shipment from another railroad.

The results presented in this section demonstrate that the identification of shipments that violate the R/VC $>$ 1.8 test for rate reasonableness depends on arbitrary allocations of non-causal costs to individual shipments. These results also argue against using URCS "variable costs" to set a reasonable price for a shipment because plausible re-allocations of non-causal costs from the URCS process can lead to significant changes in the value of the URCS "variable cost" and the R/VC value for a shipment.

Table 6 2013 R/VC by percentile movement and alternative definitions of URCS VC—railroad differences

Actual RR	Centile	Revenue/variable cost						
		Actual	Min-Depr	Max-Depr	Min-ROI	Max-ROI	Min-Depr and ROI	Max-Depr and ROI
Farm products								
6	10	1.11	1.18	1.11	1.21	1.06	1.30	1.06
1	20	2.18	2.44	2.01	2.18	1.74	2.44	1.63
1	40	2.56	2.87	2.36	2.56	2.05	2.87	1.92
7	50	2.44	2.86	2.39	2.47	2.02	2.90	1.99
7	60	1.70	1.78	1.66	1.71	1.48	1.79	1.44
6	70	1.01	1.09	0.87	1.08	0.94	1.18	0.83
1	80	1.00	1.08	0.93	1.00	0.91	1.08	0.85
5	90	1.96	2.41	1.93	2.16	1.87	2.71	1.84
6	90	2.00	2.08	2.00	2.20	1.84	2.30	1.84
Chemicals								
5	10	1.29	1.37	1.29	1.48	1.29	1.59	1.29
1	20	1.35	1.39	1.31	1.35	1.19	1.39	1.15
1	30	1.12	1.14	1.10	1.12	1.05	1.14	1.02
7	40	1.82	1.91	1.80	1.84	1.64	1.93	1.62
7	50	2.51	2.65	2.46	2.53	2.18	2.68	2.15
7	60	2.98	3.14	2.93	3.01	2.64	3.17	2.61
7	80	4.86	5.15	4.81	4.92	4.34	5.22	4.30
6	90	5.25	5.48	5.25	5.57	5.13	5.83	5.13
1	90	4.00	4.00	3.86	4.08	3.58	4.09	3.47
Coal								
1	10	1.25	1.29	1.16	1.25	1.00	1.29	0.95
1	20	1.66	1.71	1.54	1.66	1.32	1.71	1.24
1	30	1.74	1.79	1.61	1.74	1.39	1.79	1.30
4	50	1.85	1.91	1.75	2.04	1.66	2.11	1.58
4	60	2.25	2.31	2.13	2.46	2.03	2.54	1.94
7	70	2.93	2.98	2.40	2.93	1.79	2.98	1.58
6	80	3.32	3.49	2.74	3.94	3.31	4.17	2.73
6	90	4.94	5.35	4.94	5.56	4.66	6.09	4.66
4	90	3.13	3.16	3.01	3.45	2.84	3.48	2.74
Petroleum								
1	10	1.32	1.36	1.27	1.32	1.17	1.36	1.13
4	20	1.39	1.42	1.34	1.47	1.30	1.50	1.27
7	30	1.77	1.87	1.74	1.79	1.55	1.89	1.53
4	40	1.67	1.71	1.62	1.77	1.57	1.82	1.52
1	50	1.73	1.77	1.68	1.73	1.58	1.77	1.54
7	60	2.26	2.37	2.25	2.28	2.07	2.40	2.06
7	70	2.73	2.88	2.70	2.76	2.43	2.91	2.41

Table 6 continued

Actual RR	Centile	Revenue/variable cost						
		Actual	Min-Depr	Max-Depr	Min-ROI	Max-ROI	Min-Depr and ROI	Max-Depr and ROI
1	80	2.02	2.05	1.97	2.02	1.90	2.05	1.86
7	90	2.10	2.17	2.10	2.17	2.08	2.24	2.08

5 Using Costs to Set Regulated Prices for Multiproduct Firms

This section discusses the challenge faced by the STB in using the economically valid cost concepts that were defined in Sect. 3.2 to determine whether a shipment price is excessive or set a reasonable rate for a shipment if the actual rate charged is deemed excessive. Even with perfect information on the incremental cost of a shipment, the regulatory challenge of what is an unreasonable price for a shipment is isomorphic to the question of what is an unreasonable mark-up over the marginal cost or average incremental cost of the shipment. The presence of substantial economies of scope and scale in the provision of rail shipments and the existence of many shipments that are exempt from rate relief make even perfect cost information significantly less useful for determining an excessive shipment rate.

Consider the pricing decision of a profit-maximizing railroad in the absence of regulatory restraint on product prices. Let $D_j(P_j)$ equal the demand for shipments of product j by the railroad between two locations. For simplicity, assume that each demand only depends on the price that is charged by the railroad for that product. This assumption does not change any of our conclusions, but only simplifies the analysis. The demand for tons of rail shipments of product j depends on the competition that the railroad faces from other modes of transportation for these shipments. Consequently, we would expect the demand curves to differ across the M goods. Let $P = (P_1, P_2, \ldots, P_M)$ the vector of prices that are charged by the railroad for shipping each of the M goods.

An unregulated railroad's profit maximization problem can be written as:

$$\max_{P \geq 0} \pi(P) = \sum_{j=1}^{M} P_j D_j(P_j) - C(D_1(P_1), D_2(P_2), \ldots, D_M(P_M)). \tag{9}$$

The price vector that solves this problem, P*, yields the following first-order condition for profit-maximizing pricing of shipments each good by the sold by the railroad:

$$\frac{P_j^* - \frac{\partial C}{\partial q_j}}{P_j^*} = -\frac{1}{\eta_j} \quad (j = 1, 2, \ldots, M), \tag{10}$$

for $j = 1, 2, \ldots, M$, where $\eta_j = \frac{\partial D_j(P_j)}{\partial P_j} \frac{P_j}{D_j(P_j)}$ is the own-price elasticity of the demand for shipments of good j and $\frac{\partial C}{\partial q_j}$ is the marginal cost of shipping q_j tons of good j. This first-order condition implies that it is extremely unlikely that even for the same origin and destination pair, the same number of tons shipped, and the same marginal cost of a shipment, a profit-maximizing railroad would set either the same dollar per ton price or the same markup for two goods. This outcome occurs because the own-price elasticity of demand is likely to differ across goods and shippers.

For the case of a regulator that sets the vector of prices to maximize the sum of consumer and producer surplus across all products shipped subject to the constraint that the railroad is revenue adequate—it earns zero economic profits—yields the following inverse elasticity-of-demand pricing rule:

$$\frac{P_j^* - \frac{\partial C}{\partial q_j}}{P_j^*} = -\frac{\kappa}{\eta_j} \quad (j = 1, 2, \ldots, M), \tag{11}$$

where $0 < \kappa < 1$. Equation (11) is a first-order condition for the following optimization problem:

$$\begin{gathered}\max_{P \geq 0} \sum_{j=1}^{M} \int_{P_j}^{\infty} D_j(s_j) ds - C(D_1(P_1), D_2(P_2), \ldots, D_M(P_M)) \quad \text{subject to} \\ \sum_{j=1}^{M} P_j D_j(P_j) - C(D_1(P_1), D_2(P_2), \ldots, D_M(P_M)) = 0.\end{gathered} \tag{12}$$

Therefore, both the unregulated railroad and the total surplus-maximizing regulator mark up prices over marginal cost using the inverse elasticity rule. The only difference is that the regulator sets proportionately lower mark-ups over marginal cost because of its desire for the railroad to earn zero economic profits. This result also demonstrates that even if the regulator knew the firm's multiproduct cost function, $C(q_1, q_2, \ldots, q_M)$, it would still need to know the demand function for each product—$D_j(P_j)$ ($j = 1, 2, \ldots, M$)—in order to find the optimal mark-ups for each product to determine the inverse elasticity of demand for each product and value of the constant k that sets the appropriate mark-up over marginal cost for each product that is sold by the railroad so as to recover only the railroad's total production costs.

This logic implies that knowledge of railroad's multiproduct cost function is of little use in determining if the price that the railroad charges for a shipment is excessive or what should be a reasonable price because the existence of significant economies of scope and scale in the provision of rail shipments implies that a non-trivial fraction of the railroad's costs are common to all shipments. Even with complete knowledge of the railroad's cost function, the regulator is left with the extremely challenging tasks of setting the appropriate mark-up over marginal cost for each product to ensure that the railroad is revenue adequate. When the railroad also provides products that are exempt from rate relief, this process becomes even more complex, and cost information is even less useful for determining a reasonable price for shipments that can be challenged as being excessive.

It is important to note that there is no guarantee that the value of Pj* that solves either (9) or (12) is less than $C(0, 0, \ldots, q_j, 0, \ldots, 0)/q_j$: the Stand-Alone Average

Cost of q_j. Depending on the common costs that are associated with providing rail service between the origin-and-destination pair that is associated with q_j, the welfare-maximizing or profit-maximizing price could be above or below the Stand-Alone Average Cost of q_j. Moreover, if the sunk cost of entry to compete against the incumbent railroad for this origin-and-destination pair is non-zero—which is clearly a very reasonable assumption for rail service—then the incumbent railroad could charge a price above the Stand-Alone Average Cost of q_j indefinitely without triggering entry.

Any prospective entrant knows that it is unlikely to recover its sunk costs of entry because the incumbent railroad is likely to set a price below its Stand-Alone Average Cost after the firm enters. This fact provides another argument against the Stand-Alone Average Cost as an upper bound on a reasonable price for a shipment.

If (at the profit-maximizing value of P*) the railroad was more than revenue adequate, it would be possible for the STB to set a price for q_j that is lower than P_j* and still leave the railroad (at least) revenue adequate. However, it is also possible that setting a price above the Stand-Alone Average Cost of q_j may be necessary to ensure revenue adequacy of the railroad. Suppose that for the profit-maximizing value of P*, the STB decides that P_j* is excessive. If the railroad is just revenue adequate at this price vector, then reducing the price charged for q_j will render the railroad revenue inadequate. In this case, the STB would run afoul of its regulatory mandate to ensure that the railroad is revenue adequate by reducing the price charged for q_j, even if P_j* was above the Stand-Alone Average Cost of q_j.

All of these examples illustrate significant remaining regulatory challenges that face the STB even if it knew firm’s multiproduct cost function, $C(q_1, q_2, \ldots, q_M)$. These results and those from the previous sections argue against attempting to improve the STB’s railroad cost methodology in order to address its regulatory mandate to protect shippers against excessive rates. Rather than rest on cost methodologies, we recommend an alternative price benchmarking approach for providing rate relief that recognizes the substantial number of shipment rates that are presumed to be the result of competitive market mechanisms.

This approach leverages the fact that currently many shipments move at prices that are exempt from regulation because the STB has determined that the railroad faces adequate competition from trucking or at negotiated contract prices that are exempt from regulation for the life of the contract. This set of shipments from the STB’s Waybill Sample is used to construct a predictive model relating the shipment price in dollars per ton-mile to observable shipment characteristics such as the product shipped, route distance, tonnage shipped, characteristics of the railroads used to complete the shipment, and characteristics of the origin and destination of the shipment. This predictive model is used to construct a price benchmark for a proposed shipment based on these same characteristics. If the price charged for a shipment that has not been exempted from rate relief exceeds this price benchmark, then the shipper would be eligible for regulatory review by the STB of the price charged. National Academies of Sciences (2015) report recommended an arbitration process for setting the appropriate price in those instances when the STB has determined that initial price charged was the result of market dominance.[22]

6 What Cost Information Should be Collected by STB

Given our recommendation to abandon the use of URCS "variable costs" in the determining whether a shipper should be able to obtain rate relief and what rate should be set if this relief is granted and instead pursue a price benchmarking approach, an important question to address is whether the STB should continue to collect and compile railroad cost data at all. There are a number of remaining regulatory tasks that the STB can carry out more effectively if it has detailed railroad cost data that are compiled in a consistent manner across a number of years. For this reason, we support a continued collection of railroad cost data, although given the sheer volume of information currently collected in the STB R1 data form, we believe that significant streamlining is possible.

There are four basic areas where cost data would be useful for the STB in carrying out its regulatory mandate under the Staggers Act: The first area is the need to regulate the quality of rail service. With cost and output data compiled in a consistent fashion across railroads, the STB can benchmark the performance of railroads against other railroads that perform similar operations or supply similar services.

A second related area is the need to assess infrastructure adequacy. By compiling cost and physical investment data in a consistent fashion across railroads, the STB can more easily make an assessment of adequacy of the infrastructure of each railroad. The final two areas where cost and output data could be useful to collect are monitoring: (1) the adequacy of operating and maintenance activity by the railroads; and (2) the level of effort and expenditures that are devoted to railroad safety.

Streamlining the STB cost and output data collection efforts to compile consistent data across railroads and over time would significantly improve the STB's ability to achieve its regulatory mandates under the Staggers Act and reduce the administrative and regulatory burden that faces railroads in supplying cost and output data to the STB.

7 Concluding Comments

The 4R Act of 1976 and the Staggers Rail Act of 1980 placed a greater reliance on the market mechanisms to set railroad rates. Regulators have jurisdiction only if the revenue-to-variable-cost ratio exceeds 180 % and if they find that competitive pressures are not present. If these conditions are satisfied, the reasonableness of a rate is considered on the basis of Stand-Alone Costs (SAC) or alternative benchmarks. In both this initial threshold test in the process of assessing market

[22] The benchmarking approach is discussed in further detail in the National Academies of Sciences Report (2015).

dominance and in the rate reasonableness consideration, the Uniform Rail Costing System variable cost of a shipment plays an important role.

Current STB procedures require the "variable cost" of a shipment to be calculated as the first step for a shipper to obtain rate relief. This calculation was originally given using Rail Form A; in 1989 the Uniform Rail Costing Systems (URCS) replaced Rail Form A.

In this paper, we critically reviewed the URCS methodology and concluded is that it is an arbitrary accounting cost allocation procedure that is based on econometric models that are unlikely to be representative of how incremental rail costs are incurred. The result is that URCS "variable costs" are unlikely to have any meaningful relationship to the increase in railroad costs that are caused by providing a shipment and are therefore of no use to a rational railroad operator in making pricing or operating decisions. Indeed, our analysis of shipment revenue-to-variable-cost ratios with the use of the URCS "variable cost" of a shipment implies that the pricing of a sizeable fraction of shipments in the Waybill Sample would be inconsistent with rational behavior by the railroad.

In addition, we find large differences in the R/VC ratios for different railroads that earn the same revenue and provide the same shipment, because of different values for the URCS "variable costs" for each railroad. Finally, we find that URCS variable costs contain significant allocated cost components—depreciation and return on investment—that do not vary with the ton-miles shipped. Hence, we conclude that URCS is fundamentally flawed and should be abandoned.

In terms of rate reasonableness assessments, we demonstrate that if economically valid measures of the cost that is caused by a rail shipment could be obtained, it would not solve the problem of identifying an unreasonable rate, but would simply transform it into the problem of determining an unreasonable markup over the incremental or marginal cost of shipment. Because substantial portions of rail costs do not vary with ton-miles shipped or composition of outputs, railroads must price movements above both incremental and marginal cost to be financially viable. While some of the features of URCS can be improved and some have been improved, it is fundamentally flawed and alternative approaches to providing rate relief to captive shippers should be considered.

For the reasons presented in the previous sections, we consider URCS unfixable and therefore it should be abandoned. In addition, we find that SAC tests for rate reasonableness should be replaced. Of course, an alternative should be proffered. As pointed out in a recent National Academy of Sciences/Transportation Research Board (2015) report and noted in this paper, under partial deregulation, many movements have been "exempted" from reasonableness consideration, and still others are moved under confidential contracts between shippers and railroad, which are also not subject to rate reasonableness consideration. The remainder, the non-exempt and non-contract, movements still remain subject to rate regulation by the STB.

As is illustrated in this study, benchmarks can be established using the Waybill Sample for the exempt and contract movements when competitive options exist, and these can be used to judge the reasonableness of tariff rates. The result is relatively simple to understand and apply, and we believe that it ameliorates the conceptual problems inherent in the current approach to the regulation of railroad rates.

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Appendix

In this appendix, we illustrate that the cost concepts that were described in Sect. 3.2—the incremental cost of a shipment and marginal cost of shipping an additional ton do not require the assumption of cost minimization. To understand this result, consider the following derivation of a firm's cost function given its technology set T.

Let x equal the K-dimensional vector of inputs, such as labor, materials, energy, machines, equipment, and all other factors that the firm can use to produce its output and q the M-dimensional vector of outputs. The technology set that faces a firm is the set of vectors q that are technologically feasible to produce using the vector of inputs x. We introduce the following notation:

$$\mathrm{T} = \left\{ \begin{pmatrix} x \\ q \end{pmatrix} | q\, can\, be\, produced\, using\, x \right\}. \tag{13}$$

The technology set only gives technologically feasible pairs of the vector of inputs and outputs. Specifically, it allows for the fact that inputs can be wasted. Typically if the point $(x', q')'$ is in the technology set, then the points $(x^{*\prime}, q')'$ and $(x', q^{*\prime})'$ are also in the set if every element of x^* is greater than or equal to the corresponding element of x and every element of q^* is less than or equal to the corresponding element of q. This means that if q can be produced with x, then it can be produced using a vector of inputs that uses more of at least of one input. If x produces q, then it can also produce q^*: a vector of outputs that is smaller than q in at least one element.

As discussed in Panzar (1989), a multiproduct firm's minimum cost function is derived from solving the following optimization problem:

$$\min_{x \geq 0} \sum_{j=1}^{K} w_j x_j \text{ subject to } (x', q')' \in \mathrm{T}. \tag{14}$$

The solution to this problem yields the vector of cost-minimizing input choices $x_j{}^*(w, q)$ ($j = 1, 2, \ldots, K$) given the K-dimensional vector of input prices, w, and the M-dimensional vector of output levels q. The firm's minimum cost function is:

$$C^*(w, q) = \sum_{j=1}^{K} w_j x_j^*(w, q). \tag{15}$$

Panzar (1989) discusses the regularity conditions on the firm's technology set that are necessary for a marginal cost function to exist for each of the M products. Under these conditions, the relationship between the marginal cost function and the increment cost function given in Eq. (8) in the text holds for each of the M products.

Suppose that V(w, x, α) is the firm's objective function for setting its production plan. Assume that for a fixed value of the vector α, this function is increasing and continuously differentiable in w and x. The vector α represent factors impacting the firm's production plan. Solving following optimization problem:

$$\min_{x \geq 0} V(w, x, \alpha) \text{ subject to } (x', q')' \in T, \tag{16}$$

yields the vector of optimal input choices, $x_j^b(w, q, \alpha)$ (j = 1, 2, …, K). The firm's behavioral cost function for this objective function and value of α is:

$$C^b(w, q, \alpha) = \sum_{j=1}^{K} w_j x_j^b(w, q, \alpha). \tag{17}$$

Under the above assumptions on V(w, x, α) and Panzar's (1989) assumptions on T, the marginal cost function that is associated with this behavioral cost function exists for each product, and the area below this marginal cost function up to q_i gives the incremental cost of q_i. Consequently, so long as the railroad has a stable production plan that is determined by the same objective function—V(w, x, α) for a fixed value of α—stable marginal cost and incremental cost functions can be computed that can be used for railroad pricing and operating decisions.

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