Linking Service Quality with Price Caps:

the Postal Service Case

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A. Introduction

This paper proposes a means for adjusting Postal Service price caps for changes in service quality, yielding a Pareto efficient result. The idea is relatively straightforward – current Postal Service rates would be adjusted along a "share line" according to changes in service quality. By revealed preference, any change in Postal rates and service quality implies higher profits for the Postal Service, under a profit maximizing motive. However, the effect on mailers is uncertain and is dependent on allowed rate changes for any given change in service quality. A Pareto efficient share line would allow the Postal Service and all mailers to gain through changes in the existing rate structure.

In order to sketch out the main features of such a system, the paper assumes that the Postal Service provides a single mail product with the current rate (the price cap) allowed to change based on variations in the average number of days to delivery. For First Class Single Piece mail, the Postal Service currently gathers speed of delivery data (number of days to delivery) for sampled pieces, from which it is able to calculate the average number of days to delivery. However, it uses these data to report on the percentage of mail meeting speed of delivery standards instead. The Postal Service is also in the process of instituting an Intelligent Mail Barcode (IMB) system that will eventually provide the same capabilities for all First Class Mail Presort and Standard Mail pieces. Therefore, the described model might be viewed as addressing the current capability with the First Class Single Piece "product". A richer, multi-product model would address future performance standards and monitoring capabilities when IMB is fully in place.

The model presented in this paper is an extension of previous work. Spence (1975) initially sets forth the idea of a price-quality contract curve along which increases in consumer surplus or monopoly firm profits are impossible without reductions in welfare to the second party. Therefore the curve describes the Pareto efficient subset of all possible price-quality combinations. Crew and Kleindorfer (2009) propose a modified price cap, where Postal rates are allowed to increase (decrease) when a postal operator commits itself to a service quality increase (decrease). Further, they show that a profit maximizing postal operator has an incentive to increase current service quality and price under a modified price cap regime.

The Crew and Kleindorfer proposal is in response to well known information asymmetries facing postal regulators when attempting to set quality standards. High powered reward structures such as price caps incentivize postal operators to reduce operating costs in the presence of these asymmetries, perhaps at the expense of some deterioration of service quality. Thus the traditional price cap regime can work well when service quality is unverifiable and is of secondary importance (Sappington 2005). In other instances where these limitations do not apply, regulators can control service quality directly by setting minimum standards. However, even assuming a well informed regulator, the welfare effects of setting minimum standards can be ambiguous when mailers select among different price-quality combinations offered by the firm (Besanko et al. 1987).

Modifying the traditional price cap regime does not absolve the regulator completely from the asymmetry dilemma. As noted by Crew and Kleindorfer, the regulator must still be informed regarding mailer incremental willingness to pay for higher service quality if overall welfare improvement is the objective. Thus, the regulator must still know the structure of mailer demand along both the price and quality dimensions in order to set the appropriate share line along which price and quality are "traded". The present model therefore attempts to sketch out how this share line might be set to induce a Pareto efficient move away from the current price cap and service quality outcome, within the limitations of the single product assumption.

The rest of the paper is organized as follows. The next section presents the structure of the basic model and the properties of the Pareto efficient share line along which the Postal Service would be able to trade price for quality. In the interests of generality, the analysis refers to a "postal operator" instead of the Postal Service per se, but the inferences to the latter are obvious. The next section provides an application of the model that investigates how the Postal Service would react if delivery frequency changes were accompanied by changes to the price cap. Delivery frequency is an important speed of delivery driver. Therefore changes to the current six day standard might yield non-trivial welfare gains when rates are allowed to vary along the prescribed share line. The last section summarizes and comments on further research.

B. The Model

Assume, initially, that a monopoly postal operator offers a single product at a uniform rate and days to delivery to two groups of mailers. The uniformity requirement is imposed by the regulator as part of the USO. Mailers within each group are the same in number and are homogenous with respect to their demand characteristics. However the first set of mailers value speed of delivery more highly than the second, and therefore demand less volume under the uniformity requirement. We also assume that costs per mail piece are constant with respect to volume but vary directly with speed of delivery. Also, transportation, mail processing and delivery requirements for each piece entered are the same per group. Therefore, the same speed of delivery generates the same unit cost for both groups.

Mailer surplus is of the form $V_i = U(x_i) - x_i s\theta_i - x_i p$ where $i = h, l$, x_i is mail volume for group i (either high or low value), s is the average days to delivery offered by the post, p is the price charged and θ_i is a speed of delivery value parameter specific to each group. The standard surplus maximizing condition with respect to volume applies: $U'(x_i) = s\theta_i + p$. The demand function for group i is then $x_i = D(s\theta_i + p)$. Since $\theta_h > \theta_l$, it follows directly that $x_h < x_l$. Notice that the demand function written in this way indicates that demand is a function of a net price $p_i = s\theta_i + p$ which is higher than the observed price p by the loss in marginal value caused by the number of days to delivery $s\theta_{i.}$ The loss in marginal value is greater for the high value mailers, and it is this loss which causes their demand to be lowest even though the price charged is uniform.

The profit function facing the postal operator can then be written as:

$$\pi(s,p) = [D(s\theta_h + p) + D(s\theta_l + p)][p - u(s)] - F,$$

where the unit cost function $u(s)$ is convex and negatively sloped. The first order conditions with respect to p and s are then:

$$\frac{\partial \pi}{\partial p} = D'(p_h)[p - u(s)] + D(p_h) + D'(p_l)[p - u(s)] + D(p_l) = 0$$

$$\frac{\partial \pi}{\partial s} = D'(p_h)[p - u(s)]\theta_h - D(p_h)u'(s) + D'(p_l)[p - u(s)]\theta_l - D(p_l)u'(s) = 0$$

where $p_h = s\theta_h + p$ and $p_l = s\theta_l + p$. Assuming a concave profit function, the second order profit maximizing conditions for p and s are fulfilled at the indicated values.

Now assume these maximizing values are p_m and s_m. The regulator subsequently keeps the uniformity requirements but imposes a price cap $p_c < p_m$. We are interested in determining the effect on s from lowering p to later show how the monopolist reacts along a share line when moving away from p_c. Using $ds/dp = -\pi_{sp}/\pi_{ss}$ and $\pi_{ss} < 0$ from concavity of the profit function, it is clear that the marginal effect of p on s takes on the same sign as the cross effect π_{sp}. The latter is defined by:

$$\pi_{sp} = D''(p_h)[p - u(s)]\theta_h + D'(p_h)[\theta_h - u'(s)] + D''(p_l)[p - u(s)]\theta_l + D'(p_l)[\theta_l - u'(s)].$$

From $u'(s) < 0$, the second and fourth terms are negative. Therefore $D'' \leq 0$ is sufficient for $\pi_{sp} < 0$ from which $ds/dp < 0$ follows as well. The intuition of lower service quality, instigated by a price cap, is definitely fulfilled when demand is concave. In this instance, it is always profit maximizing for a postal operator to increase the number of days to delivery from the s_m level in response to a price cap.

Suppose the firm is allowed to vary its price from the cap according to the restrictions $s \leq g(p_c) - k(p - p_c)$, $k > 0$, where:

$$g(p_c) = argmax_s[D(s\theta_h + p_c) + D(s\theta_l + p_c)][p_c - u(s)] - F,$$

That is if the firm chooses to charge some price p different than the existing cap, then it must change the average number of days to delivery, from the existing optimal level $g(p_c)$, by at least the amount $-k(p - p_c)$. The rate of adjustment parameter k is set by the regulator. The firm's task is now to maximizing profits subject to the restrictions. Converting the price restriction to the equality $s = g(p_c) - k(p - p_c) - E$, then allows direct substitution for s in the profit function: $h(E, p) = \pi(g(p_c) - k(p - p_c) - E, p)$, subject to $E \geq 0$.

The firm's first order conditions with respect to p and E are then: $h_p = -k\pi_s + \pi_p = 0$, and $h_E = -\pi_s \leq 0, E \geq 0, -\pi_s E = 0$. Clearly, if the slack variable E is positive, meaning that the service adjusted price cap is not binding, then $\pi_s = 0, \pi_p = 0$ and we are back to the monopoly solution. This can only happen if s increases when p decreases so that $s_m < g(p_c)$

when $p_m > p_c$. In that case, it is clear that if the value for k is set arbitrarily close to zero, then p_m can be reached at a corresponding s value along the share line that is still higher than s_m. The operator can then stay at p_m and reduce s to s_m to reach the monopoly solution. On the other hand, if service quality increases with a price reduction, then $s_m > g(p_c)$. In this instance, any increase in the price towards its monopoly value means that s must decrease from $g(p_c)$, along the share line, and move further away from s_m so that the monopoly solution is precluded. Finally, if the service quality restriction binds, then the optimal solution requires $\pi_s > 0, \pi_p > 0$. An unregulated monopolist still has an incentive to increase both the average number of delivery days and price at the new cap. The effect on profits for a small price increase from p_c can be summarized by the following proposition.

Proposition 1: With a service-adjusted price cap, a profit maximizing firm can always increase profits by raising price a small amount from the current ceiling price, regardless of the required marginal increase in service quality.

Given a price cap lower than a monopolist's unrestricted profit maximizing price, the firm sets s so as to maximize profits at p_c. Therefore, $\pi_s = 0$ at that point yielding $h_p = -k\pi_s + \pi_p = \pi_p$. The marginal effect on profits from a small price increase and the required change in service quality is fully determined by the marginal effect from price alone. Further, it can be shown that $\pi_p > 0$ with $p_c < p_m$ when the profit function is concave. Hence, the operator can increase profits by a small rate increase above p_c. The appendix demonstrates $\pi_p > 0$ following $p_c < p_m$ with concavity of the profit function.

The effect on surplus for mailer i from the price and service quality improvement along the share line can be determined by substituting $x_i = D(s\theta_i + p)$ into $V_i = U(x_i) - x_i s\theta_i - x_i p$. We get:

$$V_i(s, p, \theta_i) = U[D(s\theta_i + p)] - D(s\theta_i + p)(s\theta_i + p).$$

The right hand side shows surplus as a function of the service adjusted price $s\theta_i + p$. Assume initially $E = 0$ and substitute for s in V_i to give $V_i(g(p_c) - k(p - p_c), p, \theta_i)$. The marginal

effect on mailer surplus from any cap constrained change in p is then: $\frac{dV_i}{dp} = -k(\partial V_i/\partial s) + \partial V_i/\partial p$. Inspection of the right hand side of V_i above establishes $\frac{\partial V_i}{\partial s} = -D(s\theta_i + p)\theta_i$ and $\frac{\partial V_i}{\partial p} = -D(s\theta_i + p)$. Therefore $\frac{dV_i}{dp} = \ = D(s\theta_i + p)(k\theta_i - 1)$. The total change in surplus for mailer i in going from p_c to some arbitrary value p^* above p_c where $s^* = g(p_c) - k(p^* - p_c) \geq 0$ is then:

$$\Delta V_i = \int_{p_c}^{p^*} D[(g(p_c) + p_c k)\theta_i + p(1 - k\theta_i)](k\theta_i - 1)dp$$

This result leads to the following proposition.

Proposition 2: If $k \geq 1/\theta_l$, then for any p^* above p_c, where p^* is bounded from above by $s^* \geq 0$ and the requirement that operator profits be at least as much as at p_c, mailer surplus for the high value group increases, with no decline in surplus for the low value group. Therefore for any p above p_c subject to the indicated boundary conditions, that price yields a Pareto efficient result.

In particular, notice that efficiency requires $(k\theta_l - 1) \geq 0$, $(k\theta_h - 1) \geq 0$. If $k = 1/\theta_l$, then $(\theta_l/\theta_l - 1) = 0$ and $(\theta_h/\theta_l - 1) > 0$ and therefore the condition is satisfied for minimal increases in p. If k is greater than $1/\theta_l$, then mailer surplus evaluates as positive for both groups, and if k is less than $1/\theta_l$ then mailer surplus decreases for the low value group and the effect is ambiguous for the high value group.

The intuition behind this result is as follows. Note that $U'(x_l) = s\theta_l + p$ indicates that θ_l is the low value group's marginal willingness to pay for higher quality. That is, for a one day decline in days to delivery, that group is willing to pay θ_l more per mail piece without affecting the quantity demanded. Alternately, we can also say that for a one cent increase in the rate, low value mailers require a $.01/\theta_l$ decline in days to delivery to keep the quantity demanded the same. High value mailers would require an even smaller decrease in days to delivery, to be just as well off as before, because they value declines in delivery days more highly. Therefore any given decline in s following a price change yields a greater surplus increase (lower decline) for high value than for low value mailers. This means that if the offsetting price change is sufficient

to leave low value mailer surplus unaffected, the surplus change for high value mailers must be positive. [1]

The Pareto superior change in price and speed of delivery can also be depicted graphically. FIGURE 1 depicts the existing speed of delivery and price cap solution, p_c and s_c, at the intersections of the isosurplus lines for the high and low value mailers, s_h and s_l, and the isoprofit curve π_c. The slopes of the isosurplus lines are the negatives of the respective marginal willingness to pay values, θ_h and θ_l. Because the postal operator optimizes speed of delivery,

Effect on Profits and Mailer Surplus from the Service-Adjusted Price Cap

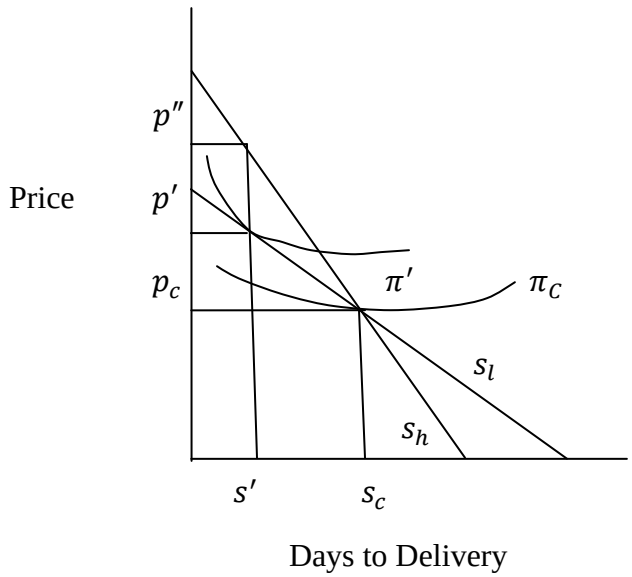

FIGURE 1

given the price cap, the slope of the isoprofit curve at that point is zero. Assuming $k = 1/\theta_l$, the postal operator can increase price and service quality by moving up s_l until a new isoprofit curve π' tangent to s_l at s', p' is reached. Since the new solution is still on s_l, low value mailer surplus is the same as before, but the high value group's surplus increases. High value mailers are now willing to pay p'' at s' but pay the lower amount p'.

[1] Another way to view this result is in terms of the effect movement along the new share line has on the service adjusted rates, p_h and p_l. With k $= 1/\theta_l$, p_l is unaffected but p_h decreases. Hence, the gain in surplus for the high value group.

Notice that the high value mailers' surplus gain is dependent on a price increase. If the postal operator chose to reduce price instead along s_l, then these mailers pay a rate that reduces their present surplus. The postal operator would choose a lower rate to increase profits if the isoprofit curve's slope through the existing point is steeper than the slope for s_l. This is the type of situation that can arise if both price and service quality are externally mandated. In that case, at least the status quo can be maintained through the imposition of a one-sided cap. The possibility of this case is explained in more detail below in the context of postal delivery frequency.

C. An Application to Delivery Frequency

The results obtained above assume that the regulator controls price while allowing the operator to set the profit maximizing service quality. However, the level of service quality is often times subject to minimum levels as part of the USO. In that case, the Pareto efficient result is not necessarily obtained by movement along the new share line, as suggested above. In particular if the USO for service quality is set too high, then the postal operator may have an incentive to decrease price and service quality along the share line instead, leading to a loss in high value group welfare.

This situation is clearly delineated by the Postal Service's six day delivery requirement which is attached to the annual appropriations rider. From the mailer's standpoint, delivery frequency can be considered a partial driver of service levels in affecting the average days to delivery. To make matters more concrete, suppose we distribute total days to delivery from the time a piece of mail enters the mail stream until the time it is delivered into a delivery component for that time and an all other activities component: $s = s_d + s_o$. To keep the analysis tractable for present purposes, we measure s_d as inversely related to a delivery frequency index $f \in (0,1]$ such that $s_d = c/f$, where c is a constant and $f = 1$ defines delivery on all days, including Sundays, to all households and establishments. The index value should be viewed as capturing the possibility of uneven delivery frequencies across weeks in order to accommodate seasonal peaks. The idea behind this formula is relatively straightforward. Given an initial value for f, if

delivery frequency is cut in half such that f is also one half its initial value, then the average time to delivery doubles because the number of intervening days between carrier deliveries doubles.

Since s_o has no bearing in our analysis, the term is dropped to now show demand for group i as $x_i = D(\theta_i c/f + p)$. [2] Therefore postal operator profits can now be shown as:

$$\pi(f, p) = [D(\theta_h c/f + p) + D(\theta_l c/f + p)][p - u] - F_o - F_d f,$$

where $F = F_o + F_d f$. That is total fixed cost is equal to the sum of delivery related fixed cost $F_d f$ and all other fixed cost F_o. Delivery related fixed cost varies proportionately with delivery frequency and, hence, the index. The unit cost is now shown as fixed since in this version, it is only affected by changes in s_o. As before, we assume that an unregulated postal operator maximizes profits with respect to p and f. The first order profit maximizing condition with respect to p is already shown. The new condition with respect to f is:

$$\frac{\partial \pi}{\partial f} = -[D'(p_h)\theta_h + D'(p_l)\theta_l][p - u]c/f^2 - F_d = 0.$$

As before, the profit function is concave and the second order profit maximizing conditions are fulfilled.

From the last, the profit maximizing solution for the delivery frequency index can also be shown in closed form as:

$$f = \sqrt{\frac{-[D'(p_h)\theta_h + D'(p_l)\theta_l][p - u]c}{F_d}}$$

Inspection of the solution indicates $\frac{df}{dp} > 0$ with concave demand because the numerator of the expression increases with p. Hence as before, average time to delivery, s_d in this case, increases as p is reduced from its monopoly value.

[2] In this demand formulation, we can think of the two groups of drop ship mailers whose average time to delivery is entirely determined by s_d.

However suppose in this case that the monopolist is unable to establish its profit maximizing delivery frequency f^* evaluated at p_c because of a higher value $f_{USO} > f^*$ required by the USO at p_c. Then $\pi_f < 0$ at $f_{USO} > f^*$ from the second order conditions as expected, indicating that profits can be increased by lowering delivery frequency. Also notice from $\frac{\partial \pi}{\partial f}$ above that:

$$\frac{\partial^2 \pi}{\partial p \partial f} = \frac{\partial^2 \pi}{\partial f \partial p} = -\frac{[(D'(p_h)\theta_h + D'(p_l)\theta_l) + (D''(p_h)\theta_h + D''(p_l)\theta_l)(p-u)]c}{f^2},$$

which is also positive with concave demand. It then follows from $\pi_p > 0$, at f^* and $p_c < p_m$, that $\pi_p > 0$ at $f_{USO} > f^*$ as well. If marginal profits with respect to price increase as delivery frequency increases, then a positive value for this marginal effect at f^* guarantees a positive value at the higher value f_{USO}. Intuitively, the higher marginal profit from increasing price can be explained by the greater marginal revenues yielded at a higher volume level generated at f_{USO} compared to f^*.

We are now in a position to show the marginal effect on profits at the existing price cap and f_{USO} when the postal operator is allowed to change price subject to the service restriction. In this case, the restriction on s_d would be of the form $s_d = c/f_{USO} - k(p - p_c)$, where c/f_{USO} is the existing s_d by definition. Substituting c/f for s_d in the restriction and solving for f then gives:

$$f = \frac{c}{[c/f_{USO} - k(p - p_c)]}.$$

Then substituting the last for f in $\pi(f, p)$ and differentiating totally with respect to p, indicates marginal profits with respect to p as:

$$\frac{d\pi}{dp} = \pi_f \left(\frac{k}{c}\right)(f_{USO})^2 + \pi_p$$

where $\frac{\partial f}{\partial p} = \left(\frac{k}{c}\right)(f_{USO})^2$. The expression evaluated at p_c and f_{USO} is indeterminate from $\pi_f < 0$ and $\pi_p > 0$. It may be profit increasing to deviate from the current cap in either direction. Clearly if f_{USO} is close enough to the profit maximizing value f^* at p_c, then the operator would

still increase profits by increasing price from the existing cap and delivery frequency from the USO value. This would shorten the average days to delivery even further. However as f_{USO} continues to increase, the negative first term increases in absolute value and the direction of price movement becomes ambiguous.

Recalling the effect on mailer group i surplus $\frac{dV_i}{dp} = D(s\theta_i + p)(k\theta_i - 1)$, if $k = 1/\theta_l$, then $\frac{dV_l}{dp} = 0$ and the low value group's surplus remains the same, regardless of the direction of price movement. However for the high value group, $\frac{dV_h}{dp} = D(s\theta_i + p)(\theta_h/\theta_l - 1) > 0$, so that a price decrease reduces surplus for this group, as suggested before. Therefore when information is asymmetric, perhaps the best the regulator can do is to ensure an outcome that is no worse than the status quo by implementing a one sided service adjusted cap with only price increases allowed.

Last, note that the regulator could set k equal to some arbitrary value greater than $1/\theta_l$, so that both mailer groups benefit by price increases. However, as k becomes larger, the likelihood of price increases is lowered because the operator's marginal profit from a higher price declines as the service-quality restriction becomes tighter (any given price change requires a higher delivery frequency and therefore lowering of days to delivery). Therefore setting k equal to $1/\theta_l$ affords the greatest chance for a Pareto efficient outcome.

D. Conclusion

Implementing service adjusted caps appears to be a viable means for increasing Pareto efficiency by encouraging service quality improvements through price increases. This paper has developed a model showing, within a single product framework, mailer demand responding to a quality adjusted price which includes a consumer willingness to pay parameter θ_i. The value for this parameter differs by mailer group and therefore the adjusted price is different for each group, although there is a single observed uniform price.

The model demonstrates that under a profit maximizing framework, Pareto efficient price increases result when the operator is free to set its service quality level at the profit maximizing amount, taking the existing cap as given. However if service quality is set higher than this amount, then the operator does not have an unambiguous incentive to increase price. Under these circumstances, the regulator can set a one sided cap that only allows for price increases. Then the Postal Service chooses between the status-quo and a Pareto efficient outcome.

The model demonstrates that when mailers value service quality differently, the setting of the price-service quality trade-off is crucial for obtaining the desired result. For the Pareto efficient outcome, the regulator sets the Service quality restriction so that service quality increases for each unit of price increase according to the inverse of the low value mailer group's marginal willingness to pay for higher quality. The required willingness to pay data can be gathered from surveys or econometric studies. However in both cases the key component is to gather or develop data by mailers or mailer groups who are known to value service quality differently. This procedure allows the low value group or groups to be distinguished so that the service quality restriction produces the Pareto efficient outcome.

The model presented here also sketches out the need for additional research. A number of obvious extensions would provide for a richer set of results, including outcomes obtained with multiple product and service quality dimensions, and relaxation of the profit maximizing motive. The last applies to public enterprises, in particular, where residual claimancy is an issue. It has been argued that to the extent that public enterprises have an incentive to reach higher than profit maximizing volume levels, they also have an incentive to generate higher than profit maximizing service quality levels to encourage volume growth. In that case, if USO mandated quality levels are lower than what a public enterprise would choose, then different results and policy prescriptions might be expected.

APPENDIX

Given any price level, the profit function for a profit maximizing operator can be written as $\pi(s,p) = \pi(g(p),p)$, where $g'(p) = -\pi_{sp}/\pi_{ss}$ from profit maximization with respect to s. Therefore:

$$\frac{d\pi}{dp} = \pi_s g'(p) + \pi_p = \pi_p.$$

Differentiating once again with respect to price yields:

$$\frac{d^2\pi}{dp^2} = \frac{d\pi_p}{dp} = \pi_{ps} g'(p) + \pi_{pp},$$

or:

$$\frac{d\pi_p}{dp} = -\pi_{ps}\left(\frac{\pi_{sp}}{\pi_{ss}}\right) + \pi_{pp} = \frac{(\pi_{pp}\pi_{ss} - \pi_{sp}\pi_{ps})}{\pi_{ss}},$$

With a concave profit function, $\pi_{ss} < 0$ and $\pi_{pp}\pi_{ss} - \pi_{sp}\pi_{ps} > 0$, therefore $\frac{d\pi_p}{dp} < 0$ follows directly. However since $\pi_p = 0$ at p_m, this just means that for all p less than p_m, inclusive of p_c, $\pi_p > 0$.

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