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ABSTRACT

As traditional methods of municipal solid waste management (MSWM) become increasingly expensive due to increased regulation, many local governments are considering cooperation as a waste management strategy. A theoretical model is used to specify a partial observability probability model in which the decision Tennessee counties made to form either a single-county solid waste region or a multi-county region. We find that, while economies of scale may be a factor in the consolidation decision, current and future levels of solid waste services are statistically more important.

Key words: regional cooperation, municipal solid waste; waste management,; regionalization

EXPLAINING COOPERATION IN MUNICIPAL SOLID WASTE MANAGEMENT[1]

INTRODUCTION

Municipal solid waste (MSW) refers to a specific portion of the generated waste stream, primarily solid waste generated by residential, commercial, institutional, and some industrial sources. Traditionally, municipal solid waste management (MSWM) has been the responsibility of local governments, with landfilling the most common method of disposal. In the early 1990's federal regulations affecting traditional methods of solid waste disposal increased the cost by as much as five- to ten-fold. In addition, the vast majority of states passed recycling laws, or adopted recycling, diversion, or waste reduction goals, and many states approved comprehensive waste management legislation requiring long-term planning (Steuteville, 1995). As MSWM has grown increasingly complex and expensive, one strategy that some communities have developed to meet new MSWM challenges is regional (e.g., multi-county, multi-community) cooperation. Cooperation is a process whereby neighboring cities, counties, or other governmental entities pool resources to address local challenges, taking advantage of the potential economies of scale associated with many aspects of MSWM. Many states have also included incentives, provisions, and/or mandates for formation of solid waste regions as an element of MSWM legislation.

Beyond the narrow arena of solid waste management, rural regions are faced with ever tightening budgetary environments and must investigate alternative means to supply necessary or mandated public goods. A common method is to exploit economies of scale by merging or consolidating service regions for public goods. Following Gyimah-Brempong's (1987)

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[1]We thank David Brasington for helpful comments on forming the data set. Responsibility for errors remains with the authors.

pioneering empirical work on consolidation of law enforcement agencies, many researchers have applied a translog cost function approach to evaluating scale efficiencies in the consolidation of rural school districts (see, among many studies, the recent analysis of rural Arkansas school districts by Dodson and Garrett, 2003). Other applications to provision of public goods in rural regions include studies of county-level extension services by Garrett (2001) and rural roads by Deller and Nelson (1991).[2] Despite its obvious appeal, the cost function approach often presents empirical difficulties in that one must have explicit measures for both inputs and outputs for public goods. Inputs and outputs may not easily be quantified, however, and a quick review of the literature will reveal some degree of anguish on the part of researchers with respect to this issue (e.g., Garrett, p. 816). Even if one has reasonably good measures for inputs and outputs, one must often assume away difficulties associated with jointness in production of outputs.

Further, it is not just scale economies that matter in the consolidation decision. A local government may enjoy scale economies of a merger in the provision of a public good yet choose not to take advantage of economies because the joint level of provision is not an optimum for the entity. For example, Jacques *et al.* (2000) show that rural Oklahoma schools can achieve the scale economies with larger school districts. The authors also show that student achievement declines as districts get larger. Given this tradeoff, a community may rationally reject a cost-saving merger if the jointly provided public good (student quality) is unsatisfactory.

Our empirical analysis concerns county-level cooperation decisions made in the aftermath of the 1991 Tennessee Solid Waste Management Act. The theoretical approach follows Miceli's (1993) model as developed to address public school district consolidation. Miceli's model

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[2] Rather than the "standard" cost function approach used by many, Deller and Nelson used a Farrell frontier model to evaluate efficiencies associated with consolidation.

allowed for mergers only if both scale economies and the joint level of public goods provision represented a Pareto improvement for all. Similar to DeBoer (1995), we use the Miceli model to evaluate consolidation of solid waste management districts, but our analysis differs from DeBoer in that we use Poirer's (1980) partial observability approach for model estimation. This model recognizes the decision to merge districts is a jointly determined outcome that is the result of independent decisions of individual districts, an important factor not addressed in DeBoer's study. The partial observability approach offers advantages over the cost function approach because it is well-grounded in economic theory yet is far less data intensive.

We first review Miceli's theoretical model explaining the joint provision of a public good, where the model is used to specify the factors important to an empirical test. The partial observability model is then reviewed, followed by a presentation of the empirical results. We then conclude with an agenda of future research.

Economies of Scale in a Model of Regional Cooperation

The argument that cooperation, or consolidation, in the provision of public goods was explicitly expressed in Miceli's (1993) version of the Tiebout model. The model recognizes that public goods, such as the provision of solid waste services, are funded out of property tax revenues. Following Miceli's notation, a budget constraint for a member of county *i* can be written as,

$$y_i = x_i + p(1 + t_i)h_i$$

where y_i is income, x_i is a numeraire, p is the price of housing, t_i is the property tax rate, and h_i is the quantity of housing. Given this income constraint, one can optimize utility and specify an indirect utility function,

$$V = V(y_i, p(1 + t_i), g_i)$$

where g_i is the level of public goods provided by the local government. According to the Tiebout hypothesis, members of a county will choose a residence so as to maximize this utility function on the basis of the cost and provision of public goods. The county's tax base is given by,

$$B_i = pH_i + S_i$$

with H_i being the total housing stock in county i and S_i being the value of non-residential taxable property in the county.

Assume that MSWM is the sole public good provided by the county. Let $c(n_i)$ denote the unit cost function for providing MSWM to the n_i residents of the county. As the derivative of the unit cost function is negative or positive, marginal costs are decreasing or increasing.[3] Economies of scale exist if the marginal cost, dc/dn_i,is less than average unit cost, $c(n_i)/n_i$. Diseconomies occur if $dc/dn_i > c(n_i)/n_i$. A balanced budget for the county is then given by[4],

$$t_i B_i = c(n_i) g_i$$

Dividing both sides by n_i and re-arranging yields,

(1) $$t_i = \frac{\frac{c(n_i)}{n_i} \times g_i}{B_i / n_i}$$

Equation (1) shows the supply of the public good in t-g space, where the slope of the supply function is defined by the per capita unit cost of provision (in the numerator) and the per capita tax base (denominator).

[3] If $dc/dn=0$ then there are no scale economies, and $c(n_i)=c(n_i+1)$.

[4] If exogenous planning and operating funds for a MSWM district are given by G_i, total revenue available for solid waste management is given by $t_i B_i + G_i$. Because planning funds were provided on only a one-time basis they are ignored in this analysis.

Assume now that a multi-county MSWM region is proposed. Such a regional administration provides solid waste services g_R which may differ from g_i. Assume further that administrative costs are shared in proportion to county population. Total costs to county i are now given by $(n_i/n)[c(n)g_R]$, where n is the regional population. The balanced budget supply of solid waste services under regionalization, t_i^R, is given by,

(2)
$$t_i^R = \frac{\frac{c(n)}{n} \times g_R}{B_i / n_i}$$

The average unit cost of solid waste services, $c(n)/n$, will fall if there are unexploited economies of scale associated with regionalization. If scale economies exist, the same level of solid waste services may be provided at a lower cost, yielding a lower tax rate for the community.

Miceli also notes (p. 351) that two counties may be currently be providing different levels of service, say g_i and g_j, and the jointly feasible level of provision, g_R, may differ from the initial amount offered by either community. Even if scale economies exist, each community must decide if the change in the level of provision is worth the change in the community tax rate. This suggests that, in addition to economies of scale measures, current levels and future levels of solid waste services will be considered by entities. Finally, Brasington's (1999) study of school district consolidation in Ohio notes that, given the relationships in (1) and (2), "...communities rich in property value will not be inclined to merge with property-poor communities unless they are sufficiently compensated by cost savings" (p. 378).[5]

Municipal Solid Waste Management in Tennessee

Tennessee passed a comprehensive Solid Waste Management Act in 1991. Passage of this Act was the first effort by the state to require all counties to meet a minimum standard level

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[5]See also Brasington, 2003.

of service in the area of solid waste management. Elements of the legislation addressed solid waste planning, collection, disposal, recycling, education, and funding as well as collection and disposal of problem wastes.

Specifically, the legislation required each county to form a solid waste region and to develop a ten-year solid waste plan for the region. The legislation included a number of required elements, including the requirement that at least 90% of all residents in the region have collection service available to them.[6] The minimum collection service level was established to be a system of drop-off convenience centers for garbage collection. Additionally, each county had to establish a minimum of one collection center for recyclable materials. Grants were provided for planning purposes, but not for ongoing operational costs.

Counties were permitted to form multi-county solid waste regions or a single-county region. According to Section 12.a.2 of the Act, "The preferred organization of the regions shall be multi-county. Any county adopting a resolution establishing a single-county region shall state the reasons for acting alone in the resolution." No upper limits were placed on region size, provided that all region members were contiguous counties.

Analysis conducted in 1991 by the University of Tennessee Waste Management Research and Education Institute (Barkenbus, *et al.*) indicates that potential scale economies exist in Tennessee (Figure 1). Savings are primarily due to declining average costs of landfilling in a sub-title D-compliant landfill up to an efficient tonnage level. Economies of scale at landfills are based 1) tonnage per day received at the facilities, 2) compaction rates achieved, as measured by in-place refuse densities, 3) percentage of landfill volume taken up by dirt required for various

[6]Another requirement was that all counties were to reduce the amount of MSW entering landfills or incinerators by 25% over a 4 year period.

cover operations, and 4) average height of refuse over the liner (CTAS, 1991). The cost savings available to larger facilities are due to the fact that more waste can be handled with relatively small increases in equipment and labor, and there is an inverse relationship between the tonnage received per day and percentage dirt required for cover. Further scale economies may be captured at the collection stage as well as disposal.

In response to the 1991 Tennessee Solid Waste Management Act, some 45 of Tennessee's 95 counties joined multi-county solid waste regions in 1993. In addition to the 50 one-county regions, one two-county, seven three-county, three four-county, and one ten-county regions were formed (Figure 2). The decision each county made regarding the formation of a solid waste region provides a natural experiment to test the Miceli model.

METHODS AND DATA

Econometric Methods. The theoretical model suggests that the major factors affecting the cooperation decision are per capita property values, population, current levels of service, future levels of service, and differences in these measures. Unfortunately, we cannot directly measure the "desire" of a county to join a region. This is because the observed outcome–joining a multi-county region or not–is the result of an agreement between two entities, not one. Thus, the appropriate method of modeling the outcome is a "partial observability" model (Poirier, 1980).

Consider the desire by county 1 to join county 2 as measured by the latent variable y_1^*, and parameterized according to $y_1^* = f(x_1; \beta)$, where the vector of explanatory variables x_1 is given by the theoretical model. The desire of county 2 to join county 1 is measured by the latent variable y_2^* and parameterized by $y_2^* = g(x_2; \beta)$. Following the standard random utility model hypothesis, we observe county 1 desiring to join county 2, denoted as $y_1 = 1$, if $y_1^* > 0$.[7] If $y_1^* < 0$, then the county does not wish to join and $y_1 = 0$. Similarly, county 2 will desire to form a regional partnership with county 1, denoted as $y_2 = 1$, if $y_2^* > 0$, with $y_2 = 0$ otherwise. The analyst does not observe either the latent variables y_1^* or y_2^*. Given the fact that both entities must agree to form a partnership, y_1 and y_2 are not observed either. Instead, what is observed is the joint outcome, $z = y_1 \times y_2$. The observed joint outcome, z, will take the value of one (an agreement) if and only if $y_1 = y_2 = 1$. If either county chooses not to cooperate, $z = 0$. Poirier terms this a partial observability model, which can be modeled as a bivariate probit with the likelihood function,

$$\ln L = \sum\nolimits_{z=1} (\ln \Phi_2[\beta x_1, \beta x_2, \rho]) + \sum\nolimits_{z=0} \ln(1 - \Phi_2[\beta x_1, \beta x_2, \rho])$$

where $\Phi_2(\bullet)$ is the bivariate normal distribution and ρ is the correlation between the two entities' choices.

Data. County level data were available from a variety of sources. MSWM regional status data were provided by the Tennessee Department of Environment and Conservation, Division of Solid Waste Assistance. The same department also provided information on the current state of solid waste collection in each county, including the presences of landfills and the percentage of unmanaged waste in a county. Population density and population growth rates were gathered from the U.S. Bureau of the Census, while property tax base data were found in the Tennessee Statistical Abstract. Means for the single-county and multi-county regions are shown in Table 1.

Following Brasington's data arrangement method, the 95 counties in Tennessee had 367

[7] The random utility model asserts that county one will desire to cooperate with county 2 if the utility of the regional partnership exceeds the utility of the single county MSWM "region", or $U^R(t_1^R, g_R) > U^1(t_1, g_1)$.

potential cooperative regional partnerships in the provision of solid waste services.[8] For any given county, a potential partner may consist of one or more counties as long as the first county is contiguous with the potential partner. The data are arranged randomly in that assigning a particular county or group of counties to "position" one or "position" two in the data set did not intentionally follow any pattern. Further, given that potential partners may consist of more than one county, we now refer to potential partners as "entities" or "units."

An entity's per capita assessed valuation measures the denominator in equation (2), while the population of the entity proxies for average unit cost of solid waste services (the numerator). Following Brasington, we anticipate that differences in assessed property valuation cause entities to be less likely to form a solid waste region. Economies of scale are measured using two different variables. The first method follows Callan and Thomas (2001) and uses population density as a proxy for scale economies, whereas the second method follows Brasington (1999) and uses population as a proxy. The economies of scale hypothesis is supported with a negative coefficient on the linear population density (population) term and a positive sign on the square root of population density (population) term.[9] It is not clear that differences in population density (population) across entities would be positively or negatively related to scale economies.

Current levels of solid waste services (g_i) are measured in two ways. First, the presence of a subtitle-D compliant landfill operated by the county or contractually available to the county is measure of current services. Secondly, the Tennessee legislation mandates that 90% of a region's residents must have access to some form of solid waste collection, a minimum level of

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[8]See Brasington's Appendix A, p.391. Prior to conducting any econometric analysis, Dr. Brasington was gracious enough to review our data arrangement.

[9]We depart from the standard "squared" non-linear term to avoid scaling issues in the maximum likelihood estimation. The negative sign on the linear term and a positive sign on the square root non-linear term will yield the familiar inverted-U shape for a function.

recycling opportunity and a 10-year assurance of disposal capacity. In essence, the legislation mandates a minimum level of g_R. Some counties satisfied all of these requirements prior to the legislation passage ($g_i \geq g_R$) whereas other counties did not satisfy any ($g_i < g_R$). We capture this legislative influence with a variable measuring the percentage of unmanaged waste in a county at the time the legislation was passed. Counties with higher percentages of unmanaged waste have "further" to go to meet state-mandated service level requirements. It is hypothesized that the more effort required on the part of a county to meet state-mandated requirements, the more likely it be to join a multi-county solid waste region to achieve (g_R). That is, the net marginal benefits of cooperation are likely to be higher for counties with infant solid waste management programs than those with well-developed programs. The difference in the percentage of unmanaged waste represents a difference in the level of current service offered by each entity, $g_i - g_j$. It is hypothesized that the greater the difference in current service levels reduces the likelihood of cooperation.

Econometric Results

Three econometric specifications were tested (Table 2). The first specification focuses only on those variables that capture the economies of scale hypothesis, current provision of solid waste services, and a measure of the specific aspects of the legislation providing the impetus for consolidation. In Model #1 of Table 2, the linear population density term is statistically insignificant, with of P-value of 0.17, whereas the non-linear term is significant. These results do not clearly support scale economies hypothesis in the decision to form a solid waste region. In contrast, the difference in per capita assessed valuation is statistically significant. This suggests that the greater the relative disparity in county wealth the less likely the entities are to form a solid waste region. Access to a subtitle-D landfill also makes the entity less likely to form multi-county region. We interpret this result as finding that entities that satisfy the one of the minimum legislative requirements (i.e., those for which $g_i \geq g_R$ prior to the legislation) are less likely to find formation of a multi-county solid waste region an improvement. Finally, as the percentage of unmanaged waste in a county increases the greater the likelihood of a regional partnership. This tendency is tempered by the negative effect of the difference on unmanaged waste: partnerships are made between those with similar unmanaged waste problems. The correlation coefficient, *Rho*, is statistically significant, indicating the decisions of the two entities is "connected" and that the bivariate approach correctly accounts for this dependence across entities. This specification did an excellent job of predicting those counties that would join a multi-county solid waste region, but predicted rather poorly those that would not join a region (less than 10% correctly predicted).

To improve the predictive capability of the model, we consider another potentially important aspect of the legislation: the 10-year assurance of disposal. This suggests that a measure of future growth in solid waste generation be reflected in the model. The second specification reflects this aspect by adding the population growth rate to the model (Model #2). In this case, the population density terms are both statistically significant if one chooses a P-value of 0.11. Larger differences across entities in per capita assessed valuation make cooperation in solid waste management less likely. The presence of a subtitle-D landfill also reduces the probability of a cooperative arrangement. Increasing amounts of unmanaged waste lead to cooperation but, again, only among those entities sharing similar level of unmanaged waste. Finally, because those units with higher population growth rates will be generating an ever greater quantity of solid waste; high growth rates reduce the probability that an entity will join a multi-county solid waste region. This model maintains the excellent prediction record of Model

#1 for those choosing to join a region (almost 80% correctly predicted), while greatly improving the predictive record for those not choosing to join (with 32% correctly predicted).

Finally. Model #3 replaces the Population Density terms with measures of Population (the measure used by Brasington and others). Similar to Models #1 and #2, this specification provides relatively weak support for the economies of scale hypothesis. The linear population term is statistically insignificant at conventional levels, whereas the non-linear term is significant at the 10% level. All other variables retain similar signs and levels of significance as the two initial specifications. This model did the best job at correctly predicting the outcome of the decision process, with an overall success rate of 56.4%.

Conclusions

The partial observability approach to modeling consolidation decisions has proved to be a useful and relatively simple analytical method that may prove of interest to other researchers. Similar to the cost function framework, the partial observability model can be well-grounded in economic theory yet avoid many of the data complications of the former. The Miceli theoretical model of consolidation provides a clear set of testable hypotheses and can be readily implemented in the empirical framework offered by the partial observability approach.

With respect to our empirical application, we find some support for economies of scale in the formation of solid waste regions in Tennessee, but the evidence is not overwhelming. While the coefficients indicate that scale economies are likely to be present, only one of these coefficients was consistently significant across specifications. Instead, the statistically strongest factors in the empirical model proved to be related to current and future levels of solid waste services. Access to a subtitle D-compliant landfill and low levels of unmanaged waste for an entity made that entity less likely to join a multi-county solid waste region relative to those without access to a landfill and with high levels of unmanaged waste. Further, those entities with high future growth in solid waste generation were less likely to join in multi-county regions. Taken collectively, the statistical results highlight Miceli's point that the existence of scale economies is a necessary but not sufficient condition for a merger between two entities. Indeed, our results suggest that the *joint* provision level and differences in current *individual* provision levels are the driving forces in the decision of Tennessee counties to join a multi-county solid waste region.

While the results presented in this paper are satisfying, the statistical models do not include other important factors that are difficult to measure. For example, Author (1996) argues that political risk and loss of local autonomy are important contributors to the cooperation decision. Dinar and Wolf (1997) echo this argument, finding that political considerations are the stabilizing influence in regional solutions that are economically feasible. Future research on cooperative outcomes should endeavor to incorporate these factors into the analysis.

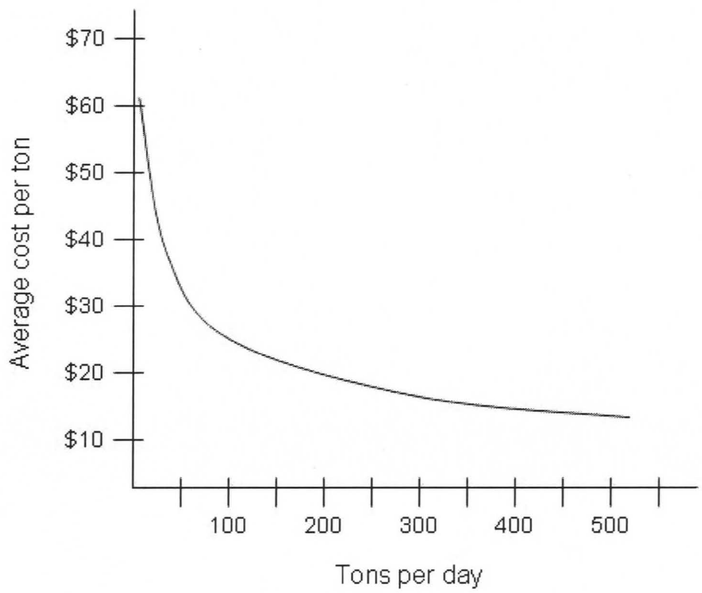

Figure 1. Average cost per ton of landfill waste in Tennessee (Source: Barkenbus, et al.)

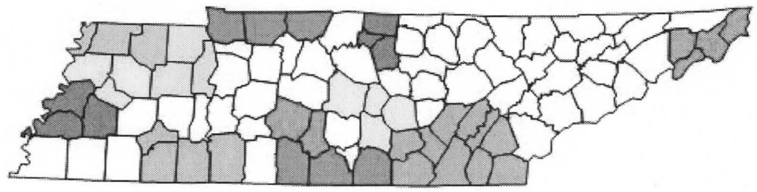

Figure 2: Solid Waste Management Regions in Tenneessee

Table 1. Variable means, standard deviations, minimum and maximum values.

Variable	Mean	Standard Deviation	Minimum	Maximum
Population Density (Persons/Sq. Mi.)				
45 "Join" Counties	79.25	82.58	18.94	495.93
50 "Not Join" Counties	126.69	207.50	15.63	1,054.41
Per Capita Assessed Value ($1000)				
45 "Join" Counties	6.68	1.49	4.89	11.06
50 "Not Join" Counties	7.35	2.66	4.43	16.76
Subtitle-D Landfill (0=No Access, 1=Access)				
45 "Join" Counties	0.31	0.47	0	1
50 "Not Join" Counties	0.54	0.50	0	1
% of Waste Unmanaged				
45 "Join" Counties	35.9	22.5	0	77.1
50 "Not Join" Counties	26.4	24.8	0	78.0
% Population Growth Rate				
45 "Join" Counties	2.73	8.27	-10.50	41.10
50 "Not Join" Counties	5.94	8.88	-5.70	39.40

Table 2. Partial Observability Models of Regional Cooperation

Variable	Model #1		Model #2		Model #3	
	Beta	**t-stat**	**Beta**	**t-stat**	**Beta**	**t-stat**
Intercept	-2.749	-0.530	-3.454	-0.622	-2.334	-0.418
Population Density	-0.373	-1.388	-0.551	-1.612		
Sqr. Root Pop. Dens.	1.171[b]	1.733	1.676[a]	2.015		
Population					-0.479	-1.495
Sqr. Rt. Population					0.455[b]	1.727
Difference in Population Density	0.053	0.271	0.105	0.560		
Difference in Population					0.004	0.227
Per Capita Assessed Valuation	-0.208	-0.281	-0.132	-0.167	-0.047	-0.059
Sqr. Root PC Assessed Valuation	1.441	0.364	1.455	0.345	-0.884	0.212
Difference in PC Assessed Valuation	-0.357[a]	-2.691	-0.442[a]	-3.355	-0.412[a]	-2.940
Sub-D Landfill	-0.355[a]	-2.209	-0.400[a]	-2.624	-0.425[a]	-1.980
% of Waste Unmanaged	1.276[a]	3.941	1.299[a]	3.744	1.453[a]	2.341
Difference in % of Waste Unmanaged	-3.696[a]	-5.408	-3.893[a]	-5.81	-3.838[a]	-5.286
Population Growth Rate			-0.022[a]	-2.842	-0.024[a]	-2.129
Difference in Population Growth Rate			-0.003	-0.953	-0.005	-1.129
Rho	-0.989[a]	-8.075	-0.997[a]	-8.982	-0.875[b]	-1.74
Log-Likelihood	-178.851		-172.991		-177.000	
Chi-Square	57.77[a]		69.496[a]		61.488[a]	
% Correct	32.4%		44.4%		56.4%	
% "Not Join" Correct	9.9%		32.5%		60.2%	
% "Join" Correct	98.9%		79.6%		45.2%	

a=significant at the 5% level, two-sided test.
b=significant at the 10% level, two-sided test.

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