THE DEADWEIGHT COSTS OF PUBLIC TRANSIT SUBSIDIES

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Abstract

This paper determines the deadweight loss of operating and capital subsidies offered US public transit systems by extending previous research by Tullock (1997). It develops a method for calculating deadweight loss and using 2006 data for 227 single mode bus transit systems it estimates cost and share equations to obtain the coefficients needed to calculate this loss. It finds that deadweight loss from the subsidies is 6.83% of total cost or $0.861 million on the average and that operating subsidy accounts for $0.780 million of it while capital subsidy's share is $0.0503 million. A further decomposition of the deadweight loss among its sources using regression shows that the incentive tier of the federal operating subsidy, federal labor protection (Section 13(c)), fleet size, and the number of maintenance facilities owned are positively associated with it while leasing instead of owning maintenance facilities and absence of dedicated funding sources are negatively associated with it.

Introduction

Subsidies can lead to resource misallocation by shortening asset life (Taubman and Rasche, 1971), and making transit systems buy more vehicles than they actually need. If they extend asset life, as these authors also note, a misallocation of resources could occur because unproductive capital must be kept for a long time and assets too costly to maintain would continue to be used. In US public transit systems, such a misallocation takes the form of the Federal Transit Administration (FTA) requiring that vehicles purchased with federal capital subsidies must be used for at least twelve years. In addition, there have been reports of inadequate internal controls leading to waste of transit subsidies. In 1992, New Jersey Transit dismissed its auditor responsible for bus subsidy programs because he failed to detect misuse of the pass-through operating subsidies it gave to Middlesex Metro Inc. of New Brunswick and Monmouth Bus Lines of Asbury Park. It was found that approximately $1 million of the subsidies these two companies received were spent on gambling trips, alimony and home furnishings (New York Times, 1992).

In another example there have been reports of misuse of monies from the US Federal Employee Clean Air Act of 1993. This act requires all federal agencies to implement national employee transit benefit programs which are reimbursements to employees for the actual costs of their transit use or monthly allowances not to exceed $110 per employee. Each federal agency pays for these benefits from its budget. It is estimated that the federal government spends about

$250 million yearly on this program.[1] At the Department of Defense, for example, 33,750 employees participated in this program in 2006 at a cost of $35.9 million (Gimble, 2007). Nation wide the benefits go to 233,000 federal employees and within the National Capitol Region $102 million are distributed to 106,000 federal employees yearly (Scovel, 2007). Audits by the General Accounting Office and other federal Inspectors General show abuse of this program by some employees in the forms of selling or transferring the transit fare cards they received to unauthorized persons, participating in this and employee parking programs, receiving subsidy amounts in excess of their monthly transit costs, and ineligible individuals receiving benefits (Kauffman 2007, Scovel 2007).

Another type of inefficiency reported is the effect of subsidies on wages. Winston (2000) notes the works of Pickrell (1985) and Lee (1987) that show that as much as 75% of transit subsidies go to increase labor wages and pad the profits of transit equipment suppliers. To illustrate his point, Winston writes that a typical Washington, DC, Metrobus driver is paid twice as much as a typical driver of one of the private bus companies in that area. Also, the subsidies create a "quiet life" by making transit systems expand their services and pursue other objectives besides cost minimization. Others are, they could make managers show expense preference for some inputs such as staff or visible inputs; they release unobligated non-federal funds for rent-seeking activities[2]; and they could lead to lax management and x-inefficiency. Or, in the context of Tullock's (1967) utility maximizing manager, they could increase cost rapidly to justify even larger subsidies if the manager's rewards are a percentage of cost. The feeling that the subsidies provide "easy money" also may lead to persistent "managerial incompetence ….without willful shirking of work force" (Berger and Hannan, 1998: 455).

In the past, several researchers have calculated inefficiency costs especially from monopoly price distortions and market power. Harberger (1954) initiated this calculation by showing that the inefficiency cost of monopoly price distortion is the sum of the lost producer and consumer surpluses denoted by a triangle bounded by a vertical line through the monopolist's output, demand and marginal cost, which later became Harberger's triangle. Using this triangle, Harberger calculated the inefficiency cost of imperfect competition in the US to be 0.1% of GNP, van Dijks and van Bergeijk (1997) estimated a weighted average welfare cost of 15% for the Dutch economy, and Solis and Maudos (2008) estimated the social cost of market power in the Mexican banking system as 0.15% of GDP.

Tullock (1967) added to this calculation when he introduced his loss triangle. Using a constant cost assumption, he showed that a budget maximizing manager would produce excess output yielding a deadweight loss equivalent to the triangle bounded on the left by demand, on the right by the vertical line going through output produced, and on top by a horizontal marginal cost line. In his model costs increase because the manager must employ more resources to produce the extra output and to increase his compensation. According to him "The true bureaucratic (*budget*) maximizer would exercise close control over costs in order to waste his resources where they would do him the most good" (p. 94). As long as this loss is less than the consumer surplus, the manager would expand output, he argues. Tullock (1998) extended his analysis to show that when subsidies are provided a similar loss triangle can be derived whose area is the deadweight cost of the subsidies.

In this paper, we extend Tullock's triangle to calculate the deadweight loss of operating and capital subsidies offered to US public transit systems. The approach followed, however, is different, in that we focus on input distortions when such subsidies are offered, calculate the deadweight loss for each input, and add them to obtain the deadweight loss of the subsidies. We estimate that the deadweight loss of operating and capital subsidies is 6.83% of the total cost of a typical single mode bus transit system or $0.861 million on the average. The amount of the subsidies going to labor that is misused is $0.440 million compared to $0.336 million and $0.085 million going to fuel and capital respectively misused. The decomposition of the deadweight loss among its sources using regression shows that federal labor protection, the number of maintenance facilities owned, fleet size and the federal formula for allocating the incentive tier of Section 5307 operating funds to transit systems are positively associated with it. The deadweight loss is smaller in transit systems that do not have dedicated local funding or own their maintenance facilities.

Background

In US, operating and capital subsidies are input specific and are offered to AMTRAK (the national intercity rail company), merchant marine companies in the forms of construction differential[3] and operating differential subsidies and transit systems.[4] In transit systems operating subsidies cover the costs of labor, fuel and materials, while capital subsidies are for buying and rehabilitating equipment, right-of-way protection and acquisition, and corridor development to support new fixed guideways. Lately, federal legislation has changed how capital subsidies are used and who can receive federal operating subsidies. Both the Transportation Equity Act for the Twenty-First Century (TEA-21) and the Consolidated Appropriations Act of 2005 discontinued federal operating subsidies to transit systems operating in cities with more than 200,000 populations and broadened the definition of what can be done with federal capital subsidies to include maintenance and other activities. Because federal capital subsidies pay 80% of cost and operating subsidies 50% of operating losses on the margin, large transit systems welcomed this change because it requires less local matching funds when used for non-capital purposes, such as short run costs. Besides the federal government, state and local governments also offer capital and operating subsidies.

Table 1: Operating and capital funds ($ millions)

	Operating Subsidies ($ millions)						Capital Subsidies ($ millions)
Year	Real Dedicated Funds	Real Local Funds	Total Local Funds	Real State Funds	Real Federal Funds	Real Operating Subsidies	Real Capital Subsidy
1995	1013.25	2612.14	3625.39	2512.86	536.09	6674.34	4744.95
1996	1080.56	2631.29	3711.85	2601.53	380.11	6693.50	4514.90
1997	1161.12	2551.46	3712.58	2441.56	403.12	6557.26	4890.66
1998	1198.40	2685.21	3883.61	2625.40	460.86	6969.88	4842.21
1999	1371.25	2724.97	4096.22	2928.33	523.29	7547.84	5386.98
2000	1137.57	3088.73	4226.30	2884.49	577.35	7688.15	5567.36
2001	1098.08	3329.53	4427.61	3219.03	638.00	8284.64	6447.60
2002	1229.18	2970.48	4199.66	3734.63	733.41	8667.70	7141.47
2003	1382.99	3020.43	4403.42	3604.78	878.37	8886.58	7195.98
2004	1369.77	3273.85	4643.62	3553.84	1104.24	9301.69	7012.18
2005	1328.01	3409.01	4737.02	3837.43	1179.42	9753.87	6340.71
2006	1387.20	3524.40	4911.60	3806.65	1285.66	10003.92	6617.26

*Real profit is in 1982-84 constant dollars. Data for operating expenditure and total operating funds obtained from American Public Transit Association (2008). 2008 Public transportation fact book, 59th Edition. APTA, Washington, DC.

Table 1 shows real capital and operating subsidies received by US public transit systems from 1995 to 2006. In column 2 operating subsidies from dedicated sources increased from $1.013 billion in 1995 to $1.387 billion in 2008 or by 36.89% (3.35% per year) while column 3 shows that local subsidies increased from $2.612 to $3.524 billion or by 34.92% (3.17% per year). Adding these two columns together and comparing the results in column 4 to the state and federal operating subsidies in columns 5 and 6 respectively, real local operating subsidies are very large and almost equal the sum of the same subsidies from these two sources. For example, real local subsidies were $4.917 billion in 2006 compared to $1.286 and $3.807 billion in federal and state operating subsidies respectively. Column 7 shows that real operating subsidies from all sources increased steadily from $6.674 billion in 1992 to $10.004 billion in 2006, an increase of 49.89% or 4.54% per year. At the same time, in column 8, real capital subsidies increased by 39.46% from $4.745 to $6.617 billion or at a rate of 3.59% per year.

Comparatively, Table 2 shows real operating revenues and operating costs. As can be seen, real transit operating revenues grew by 39.72% or 3.61% per year while real operating expenditures grew by 35.69% (or 3.24% per year). Subtracting the total expenditures in Column 5 from the operating funds (inclusive of operating subsidies but excluding capital subsidies) in column 4, column 6 shows that transit systems in total made real after-subsidy operating profits, a result consistent with what Obeng (2000) reported. These after-subsidy profits increased almost four-fold (398.65%) from $257.12 million in 1995 to $1.025 billion in 1999, fell in 1998 to $927.47 million before rising again to $1 billion in 2001. Between 2001 and 2006, real after-subsidy profits reduced by 16.85% to $831.65 million. The same data source (American Public Transit Association, 2008) shows that between 1995 and 2006 total unlinked passenger trips increased by 29.04%, while in Table 2 real passenger revenue increased less slowly by 24.44% (2.22% per year) and real fares per unlinked passenger trip declined by 3.45% (-0.31% per year).

Table 2: Passenger Fare Revenue and Fares per Unlinked Trip*

Year	Real Passenger Revenues ($ million)	Real Fare per Unlinked Passenger Trip ($)	Real Total Operating Funds (TOF)	Real Total Operating Cost (TOC)	Real after-subsidy profit RP=TOF-TOC
1995	4462.533	0.58	11968.90	11711.75	257.15
1996	4726.769	0.59	12205.99	11689.42	516.57
1997	4701.371	0.56	12158.82	11798.19	360.62
1998	4889.325	0.56	12921.35	12109.51	811.84
1999	4971.429	0.54	13337.45	12312.18	1025.27
2000	5078.862	0.54	14078.16	13150.70	927.47
2001	5020.384	0.52	14278.94	13278.71	1000.23
2002	4807.615	0.50	14804.00	13804.34	999.67
2003	4972.446	0.53	15228.91	14484.57	744.35
2004	5174.484	0.54	15732.19	15090.42	641.77
2005	5258.116	0.54	16235.43	15511.98	723.45
2006	5553.026	0.56	16723.12	15891.47	831.65

These are in 1982-84 constant millions of dollars. Except real after-subsidy profit the data are from: American Public Transit Association (2008). 2008 Public transportation fact book, 59th Edition. APTA, Washington, DC.

Therefore, the reasons for the real after-subsidy profit are increased transit ridership, and the strong growth in real operating subsidy of 4.54% per year outpacing the growth in real operating cost of 3.24% per year. From public policy perspective, the amount of subsidy provides indications of the value the government places on public transit services; a higher amount showing a very high value and a lower amount indicating otherwise. Thus, if public transit subsidy is increasing, as we have found, it suggests that the government sees the service as essential in accomplishing some social objectives. Additionally, the sizes of the subsidies reflect the varying objectives which transit systems are called upon to achieve such as making public transit services easily available as a competitive mode of urban transport, improving air quality, mobility and accessibility, and saving energy. Transit managers accept these objectives as mandates and incorporate them into their operations such as in targeting their services to areas with most needs.

Theoretical Model

Because transit systems make after-subsidy profit, it is plausible to assume that they pursue the objective of after-subsidy cost minimization in producing outputs which satisfy their mandates. For, with real fares remaining almost unchanged, the pursuit of this objective or ridership maximization is a way to ensure that they earn after subsidy profits. Of course, it could be argued that maximizing operating subsidies from all sources would also increase after-subsidy profits. But, that could create so much wasteful expenditures such as on lobbying for subsidies that we do not consider it a viable objective. Therefore, consider a transit system that receives operating and capital subsidies from sources including federal, state and local governments and that minimizes its after-subsidy cost $wL + rK + pF - A_o(L,K,F) - A_K(L,K,F)$ subject to a production function constraint $Q = Q(L, F, K)$ where output (Q) is in terms of vehicle miles.[5] A_o and A_K are operating and capital subsidies respectively and the market prices of labor (L), capital (K) and fuel (F) are w, r, p in that order. Further, assume this transit system spends all its subsidies on these inputs. The Lagrangian of this optimization is,

$$\text{(1)} \qquad \underset{(L,K,F)}{Min} \; \ell = wL + rK + pF - A_o(L,K,F) - A_K(L,K,F) + \lambda\left(Q - Q[L,K,F]\right)$$

From the first order conditions of this minimization and for an input pair such as labor and capital, the ratio of their respective marginal products f_L and f_K is,

$$\text{(2)} \qquad \frac{f_L}{f_K} = \frac{w\left(1 - \mu_{oL}H_{oL} - \mu_{KL}H_{KL}\right)}{r\left(1 - \mu_{oK}H_{oK} - \mu_{KK}H_{KK}\right)} = \frac{w^*}{r^*} = \frac{w}{r}\,\xi_{LK}$$

Where $H_{oL} = A_o / w_L L, H_{KL} = A_K / w_L L$ and $H_{oK} = A_o / w_K K, H_{KK} = A_K / w_K K$, and the assumption of full allocation of each subsidy among the inputs implies that $\sum_i \mu_{oi} = \sum_i \mu_{Ki} = 1 \; where \, i = K, L, F.$ μ_{oi} and μ_{Ki} are the respective elasticities of operating and capital subsidy with respect to an input. For each input, the term in parentheses after its price is the proportion that a transit system pays from passenger revenue. Additionally, w^* and r^* are the respective misperceived unit prices of labor and capital[6] and ξ_{LK} is allocative inefficiency a part of whose cost is deadweight loss. This deadweight loss can be calculated by combining the information in Eq. (2) with Tullock's (1997) work whose description follows.

Consider a service that receives government subsidies. In Figure 1 Tullock (1997) shows the part of the subsidies wasted in providing this service. The demand for the service is dd; the average cost is h and it is the same as marginal cost. The subsidized average cost is c_s and the quantity demanded is Q_s. The government's cost of the subsidy is the rectangle $hbcc_s$, triangle abc is the deadweight cost (loss) if the subsidies are not a result of rent seeking activities, and the trapezoid $hacc_s$ is the benefit consumers enjoy by using the subsidized service.

Analogous to Figure 1, Figure 2 from Obeng and Sakano (2000, 2008) shows input demand when a transit system receives operating and capital subsidies. The transit system's demand for an input such as labor is dd,[7] its market wage rate is w and, before the subsidies, it employed L^* units of labor and enjoyed a consumer surplus of dwa. Because it receives operating and capital subsidies, L^* is not the quantity of labor it demands. From Eq. (2), that quantity is based upon the misperceived wage or implied price w^* at which the transit system employs L units of labor, enjoys a consumer surplus of dcw^* and incurs a total resource cost of wL and an implied resource cost of w^*L. These costs are respectively waL^*O and w^*cL^*O, and total subsidy is $wbcw^*$. The subsidies result in an increase in benefits to the firm of $wacw^*$ from which after subtracting the total amount of the subsidy $wbcw^*$ going to labor, gives a deadweight loss (DWL_L) triangle abc which is similar to Tullock's. This triangle is the portion of the subsidy going to labor wasted, lost or possibly misused. It is equal to the area aec and can be calculated as,

$$DWL_L = L\left(w_o - w^*\right) - \int_{w^*}^{w} L(w)\partial w = \left(\tfrac{1}{2}\right)(\Delta L)(\Delta w) \tag{3}$$

To operationalize Eq. (3), let η_i be the absolute value of own price elasticity of input demand and rewrite it as,

$$\eta_L = \frac{\Delta \ln L}{\Delta \ln w} \quad \textit{where} \quad \Delta \ln L = \left(L - L^*\right)/L^* \tag{4}$$

Expanding and solving this equation gives $\Delta L = L^* \eta_L \Delta \ln w$, and substituting the implied price of labor into it gives $\Delta L = L^* \eta_L (\mu_{oL} H_{oL} + \mu_{KL} H_{kL})$ where $\Delta \ln(w) = \left(w_0 - w^*\right)/w_o = (\mu_{oL} H_{oL} + \mu_{KL} H_{KLi})$. Additionally, substituting these results into Eq. (3) gives the deadweight loss from misusing some of the subsidies going to labor as:

$$DWL_L = -\frac{1}{2}(\Delta w)(\Delta L) = \frac{1}{2} w_0 L^* \eta_L (\mu_{oi} H_{oL} + \mu_{KL} A_{KL})^2 \tag{5}$$

Expressing L^* in observable terms by solving for it in $\Delta L = L - L^* = L^* \eta_L (\mu_{oL} H_{oL} + \mu_{KL} H_{KL})$ and substituting the result into Eq. (5) gives Eq. (6) as the deadweight loss from misusing some of the subsidies going to labor.

$$DWL_L = \frac{w_0 L \eta_L (\mu_{oL} H_{oL} + \mu_{KL} H_{KL})^2}{2\left(1 + \eta_L \left[\mu_{oL} H_{oL} + \mu_{KL} H_{KL}\right]\right)} = \frac{C S_L \eta_L (\mu_{oL} H_{oL} + \mu_{KL} H_{KL})^2}{2\left(1 + \eta_L \left[\mu_{oL} H_{oL} + \mu_{KL} H_{KL}\right]\right)} \tag{6}$$

Where, C is the observed total cost, S_L the observed share of an input in total cost, and all other terms are defined already. Rewriting and generalizing this equation gives,

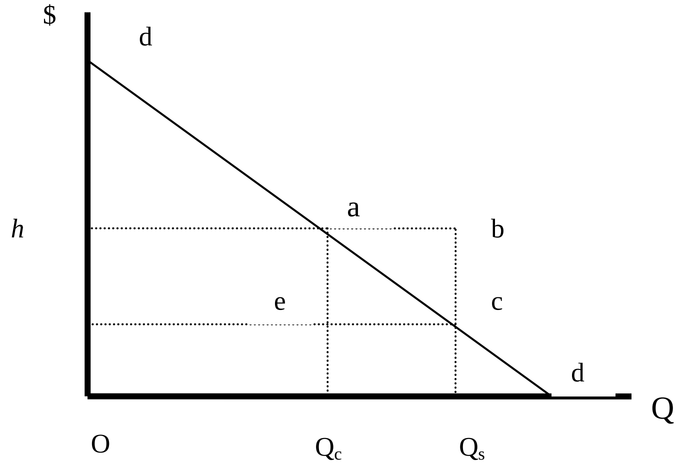
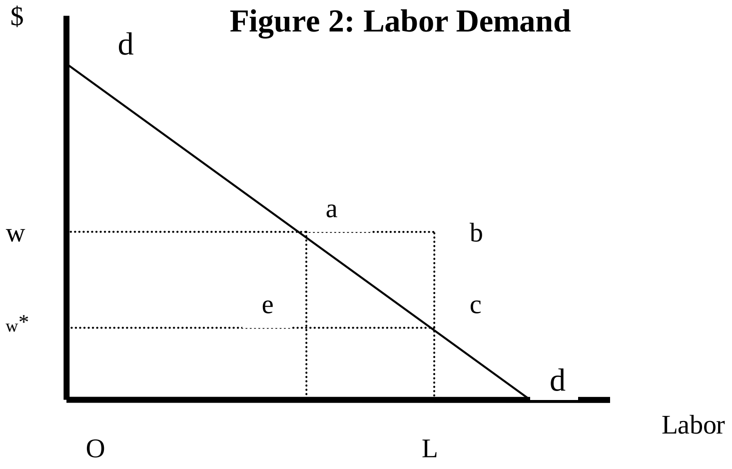


Figure 2: Labor Demand



Obviously in Eq. (7), the size of deadweight loss depends upon own price elasticity of input demand. If input demand is price elastic this loss would be large, the reverse being true if it is price inelastic. For example, if input demand is perfectly price elastic, the first term in the

(7)
cs

$$DWL_i = \frac{CS_i\left(\mu_{oi}H_{oi} + \mu_{Ki}H_{Ki}\right)^2}{2\left(\eta_i^{-1} + \mu_{oi}H_{oi} + \mu_{Ki}H_{Ki}\right)} \quad for \;\; i = L, F, K$$

denominator is a zero and deadweight loss is $0.5CS_i(\mu_{oi}H_{oi} + \mu_{Ki}H_{Ki})$. On the other hand, if it is perfectly price inelastic, the first term in the denominator becomes very large and the deadweight loss approaches a zero. Similarly, the size of the loss depends upon the amount of operating or capital subsidy received. As operating subsidy becomes very large the deadweight loss becomes $0.5CS_i\mu_{oi}H_{oi}$ and as it approaches a zero the deadweight loss disappears. Taking the sum of this equation over all inputs and dividing both sides of the result by actual total cost gives the share of the deadweight loss in this cost as:

$$\frac{\sum_i DWL_i}{C} = \frac{1}{2}\sum_i \left\{ \frac{S_i\eta_i(\mu_{oi}H_{oi} + \mu_{Ki}H_{Ki})^2}{(1 + \eta_i[\mu_{oi}H_{oi} + \mu_{Ki}H_{Ki}])} \right\} \tag{8}$$

Either Eq. (7) or (8) can be used to calculate deadweight loss. However, when Eq. (7) is used a quasi optimal amount of each subsidy can be determined under some restrictive assumptions. By observation, most of the deadweight loss occurs in the targeted input which has the largest share in cost. Operating subsidy covers short run cost and labor's share in it is approximately 66.1% (American Public Transit Association, 2008). Until recently, the target of capital subsidy was vehicle, facility and right-of way acquisition as we saw in the previous section. Therefore, most of the deadweight losses in operating and capital subsidies would be in labor and capital demand respectively. Hence, assume DWL is fixed for all inputs except the most important input in terms of cost share targeted by the subsidy. Then, write similar equations as (7) for labor and capital and differentiate that for labor with respect to A_o and that for capital with respect to A_K. Using labor as an example, that differentiation yields,

$$\frac{\partial DWL_L}{\partial A_o} = \frac{\left\{4\eta_L\mu_{oL}(w_oL + \eta_L[\mu_{oL}A_o + \mu_{KL}A_K])[\mu_{oL}A_o + \mu_{KL}A_K] - 2\eta_L^2\mu_{oL}(\mu_{oL}A_o + \mu_{KL}A_K)^2\right\}}{4(1 + \eta_L[\mu_{oL}H_{oL} + \mu_{KL}H_{KL}])^2} \tag{9}$$

$$= \eta_L\mu_{OL}\left\{ \frac{\eta_L\mu_{oL}^2A_o^2 + 2A_o\mu_{oL}B + \mu_{KL}A_K(w_oL + B)}{2(1 + \eta_L[\mu_{oL}H_{oL} + \mu_{KL}H_{KL}])^2} \right\} \qquad \text{where } B = w_oL + \eta_L\mu_{KL}A_K$$

Setting Eq. (9) to zero and solving for the optimal level of operating subsidy $(\hat{A}_o)$, we have:

$$\hat{A}_o = \left(\frac{1}{\eta_L\mu_{oL}}\right)\left(B^2 - \eta_L\mu_{KL}A_K(B + w_oL)\right)^{0.5} \tag{10}$$

$$= \frac{w_oL}{\eta_L\mu_{oL}}$$

Eq. (10) suggests large operating subsidy if the targeted input has price inelastic demand and small operating subsidy if it has price elastic demand. It also suggests large operating subsidies if the elasticity of subsidy with respect to the targeted input is very small. No operating subsidy should be given if the targeted input has perfectly elastic demand according to this equation. Similarly, the optimal capital subsidy is,

$$\hat{A}_K = \frac{rK}{\eta_K\mu_{KK}} \tag{11}$$

As shown in the appendix these optimal subsidies are the maximum that should be offered. Their values vary by transit system because input cost and own-price elasticity of input demand also vary by transit system. Dividing the operating or capital subsidy received by its corresponding optimal amount shows which transit system has excess subsidies.

Empirical Models

The determination of excess subsidy and the calculation of deadweight loss both require specifying and estimating an equation to obtain the values of the coefficients in Eq. (8). In this study these coefficients are from a cost function that does not assume cost minimization and that extends the information in Eq. (2). Recall from this equation that the implied prices of labor, capital and fuel are respectively w^*, r^*, p^* and are what transit systems misperceive as their input prices. Using these prices, total implied cost is $C^* = w^* L + r^* K + p^* F$ and its functional form is $C^*\left(w^*, r^*, p^*, Q\right)$. From Shephard's lemma, actual total cost is related to implied cost by $C = w\frac{\partial C^*}{\partial w^*} + r\frac{\partial C^*}{\partial r^*} + p\frac{\partial C^*}{\partial p^*}$ because $\frac{\partial C}{\partial w} = \frac{\partial C^*}{\partial w^*}, \frac{\partial C}{\partial r} = \frac{\partial C^*}{\partial r^*}, \frac{\partial C}{\partial p} = \frac{\partial C^*}{\partial p^*}$. Since the share of labor in total implied cost is $S_L^* = \frac{\partial \ln C^*}{\partial \ln w^*}$ and $w/w^* = 1/\left(1 - \mu_{oL}H_{ol} - \mu_{KL}H_{KL}\right)$, the first term of the actual total cost equation is $C^* S_L^*\left(1 - \mu_{oL}H_{ol} - \mu_{KL}H_{KL}\right)^{-1}$. Writing similar expressions for the other terms, substituting them into the actual total cost equation and then factorizing results in Eq. (12).

$$(12) \quad C = C^*\left\{S_L^*\left(1 - \mu_{oL}H_{oL} - \mu_{KL}H_{KL}\right)^{-1} + S_K^*\left(1 - \mu_{ok}H_{oK} - \mu_{KK}H_{KK}\right)^{-1} + S_F^*\left(1 - \mu_{oF}H_{oF} - \mu_{KF}H_{KF}\right)^{-1}\right\}.$$

Taking the logarithms of this equation gives Eq. (13).

$$(13) \qquad \ln C = \ln C^* + \ln \upsilon$$

Where, υ is the term in braces in Eq. (12) and $\upsilon - 1$ is the proportion by which actual total cost exceeds total implied cost.[8] Thus, $(\upsilon - 1)C^*$ is the amount of the subsidy or $wbcw^*$ in Figure 2. This amount is far larger than the deadweight loss abc in the same figure.

Clearly, Eq. (13) is deterministic and assumes that the exact values of C^* and υ are known. However, they are not because some of their terms are estimated and so Eq. (13) is not free of errors. Therefore, we add a random error term ε_1 to it to obtain $\ln C = \ln C^* + \ln \upsilon + \varepsilon_1$. Expanding the minimum implied cost function $C^*\left(w^*, r^*, p^*, Q\right)$ by Taylor's series up to the second order and substituting the result into, $\ln C = \ln C^* + \ln \upsilon + \varepsilon_1$, we obtain the translog equation shown in Eq. (14).

$$(14) \qquad \ln\left(C\right) = \left\{\begin{array}{l} \beta_o + \beta_L \ln(w^*) + \beta_K \ln(r^*) + \beta_F \ln(p^*) + \beta_Q \ln\left(Q\right) + 0.5\beta_{LL}[\ln(w^*)]^2 + \beta_{LK}\ln(w^*)\ln(r^*) \\ \quad + \beta_{LF}\ln(w^*)\ln(p^*) + \beta_{LQ}\ln(w^*)\ln(Q) + 0.5\beta_{KK}[\ln(r^*)]^2 + \beta_{FK}\ln(r^*)\ln(p^*) \\ \quad + \beta_{KQ}\ln(r^*)\ln(Q) + 0.5\beta_{FF}[\ln(p^*)]^2 + \beta_{FQ}\ln(p^*)\ln(Q) + 0.5\beta_{QQ}[\ln(Q)]^2 \end{array}\right\} + \ln\left(\upsilon\right) + \varepsilon_1$$

Where, the term in braces is the implied cost function and symmetry and homogeneity of degree one in input price restrictions are imposed on it. In case of symmetry, for example, $\beta_{KL} = \beta_{LK}$ and $\beta_{QL} = \beta_{LQ}$, and for homogeneity of degree one in input prices the restrictions below apply.

$$(15)\quad \beta_L + \beta_K + \beta_F = 1, \quad \beta_{LL} + \beta_{LF} + \beta_{LK} = 0, \quad \beta_{LK} + \beta_{KF} + \beta_{KK} = 0,$$
$$\beta_{LF} + \beta_{FF} + \beta_{KF} = 0, \quad \beta_{LQ} + \beta_{FQ} + \beta_{KQ} = 0$$

From the implied cost function Eq. (16) is the share of labor in implied cost.

$$(16)\quad S_L^* = \beta_L + \beta_{LL}\ln(w^*) + \beta_{LK}\ln(r^*) + \beta_{LF}\ln(p^*) + \beta_{LQ}\ln(Q)$$

Similar equations as (16) can also be written for both the shares of capital and fuel in implied total cost. Examining this equation S_L^* must be expressed in terms of actual cost share since it is unobservable. To do so we multiply $w = w^*/(1 - \mu_{oL}H_{oL} - \mu_{KL}H_{KL})$ and $p = p^*/(1 - \mu_{oF}H_{oF} - \mu_{KF}H_{KF})$ respectively by labor (L) and fuel (F) and divide each result by actual total cost (C). The results in Eq. (17) express actual cost shares of labor (S_L) and fuel (S_F) in terms of their respective implied cost shares.

$$(17)\quad S_L = S_L^*(1 - \mu_{oL}H_{oL} - \mu_{KL}H_{KL})^{-1}/\upsilon = \{\beta_L + \beta_{LL}\ln(w^*) + \beta_{LK}\ln(r^*) + \beta_{LF}\ln(p^*) + \beta_{LQ}\ln(Q)\}(1 - \mu_{oL}H_{oL} - \mu_{KL}H_{KL})^{-1}/\upsilon$$
$$S_F = S_F^*(1 - \mu_{oF}H_{oF} - \mu_{KF}H_{KF})^{-1}/\upsilon = \{\beta_F + \beta_{LF}\ln(w^*) + \beta_{FK}\ln(r^*) + \beta_{FF}\ln(p^*) + \beta_{FQ}\ln(Q)\}(1 - \mu_{oF}H_{oF} - \mu_{FK}H_{FK})^{-1}/\upsilon$$

These input shares are estimated jointly with Eq. (14) after imposing all the constraints on them including those on subsidies, i.e., $\sum_i \mu_{oi} = \sum_i \mu_{Ki} = 1 \; where\, i = K, L, F.$ Also, all variables are mean centered, except the shares of inputs in actual total cost and the ratios of the subsidies to input costs, the latter of which are allowed to take their actual values to ensure the mean firm has subsidies.

Estimating the cost and share equations as described, however, does not identify the sources of deadweight loss, but provides the coefficients μ_{oi} and μ_{Ki} needed to calculate this loss. Those sources can be identified through a second stage regression by estimating the hypothesized linear decomposition equation below:

$$(18)\quad \sum_i DWL_i = \omega_0 + \sum_i \omega_m X_m + \varepsilon_2$$

Where, the dependent variable is the sum of the deadweight losses from misusing the subsidies going to labor, capital and fuel.[9] ω and ε_2 are the set of parameters to be estimated and the error term respectively, and X_m the set of variables following. More specifically, ω gives the marginal dollar values of the variables in the decomposition equation. If it is negative (positive), an increase in the variable with that coefficient is associated with a decrease (increase) in deadweight loss. The variables with negative coefficients, therefore, provide some bases for policies to reduce deadweight losses.

Federal labor protection: A source of waste from subsidies comes from the provisions of the Federal Transit Act. Section 5333 (b) of Title 49 of the United States Code (formerly Section 13(c) of the Federal Transit Act), states that Federal funds received by transit systems as subsidies cannot be used to worsen labor conditions. Transit systems receiving these subsidies must have in place plans to protect employees who may be affected by capital acquisition or service improvements from layoffs. It requires paid training and retraining of employees whose jobs are affected by Federal assistance. For those who lose their jobs, Section 5333(b) requires transit systems to pay them a dismissal allowance not to exceed six years of their salaries and benefits. Where the job of an employee of a transit system receiving the subsidies is downgraded she must be paid a displacement allowance equal to the difference in wages in her current and previous positions. This labor protection clause limits transit systems in terms of their abilities to substitute other inputs for labor and leads to inefficiencies in the form of overuse of labor relative to capital or fuel. For example, a transit system that replaces its fleet of small buses with large ones bought with federal subsidies must protect the interests of its affected drivers by making equitable arrangements for them through negotiations with the unions representing them and having such arrangements certified by the Secretary of Labor. Evidence of labor-capital distortion can be obtained from ξ_{LK}. If ξ_{LK} is less (more) than one it shows that the subsidies make the implied price of labor more (less) than the implied price of capital leading to the substitution of capital (labor) for labor (capital). ξ_{LK} can be used in Eq. (14) to capture the effect of federal labor protection in causing allocative distortions. But, it is not because its terms are in the formula for calculating deadweight loss. Therefore, we use the ratio of total employment to fleet size (L/K) to capture labor-capital distortion.

Federal incentive tier subsidy: The federal matching formulae and the formula for disbursing federal capital and operating subsidies to transit systems also have been noted as sources of allocative inefficiency. Transit capital subsidies from federal sources require 20% local match and operating subsidies 50% match. Pickrell (1992) argues that the very small local match for capital subsidies skews investments in favor of capital-intensive programs and provides little incentive for local officials to consider less costly alternatives. Additionally, 9.2% of the Section 5307 formula grants that bus transit systems receive is incentive tier allocated based upon passenger miles squared over operating cost and it is a source of inefficiency. By penalizing transit systems with high operating costs, the formula distorts the optimal rate of substitution between labor and capital, and fuel and capital. Obeng and Azam (1995) studied the US federal formula for disbursing operating subsidies to public transit systems and derived the following equation from it:

$$f_L / f_K = \left(\frac{w}{r}\right)(1 + \varphi R). \qquad (15)$$

Where, R is the ratio of federal operating subsidy to total operating cost and φ is the elasticity of operating subsidy with respect to the incentive tier component (i.e., passenger miles squared divided by operating cost). Since R is positive, the value of $(1 + \varphi R)$ is greater than one showing that by itself the formula distorts the optimal rate of input substitution in favor of capital and leads to inefficiency in terms of overuse of capital relative to labor thereby increasing cost. We account for the incentive tier's effect by including passenger miles (PM) as a variable in the decomposition equation.[10]

Extensiveness of vehicle maintenance: Almost three decades ago, Bonnell (1981) summarized a US General Accounting Office's report on federal transit operating subsidies and their uses to identify the causes of the soaring financial crisis in public transit systems.[11] He reported that due to peaking and restrictive union contracts that prevented the use of part-time labor, transit systems were not using labor efficiently; that transit systems were not properly recruiting, training and promoting mechanics resulting in bus repairs that were improperly done; that transit systems did not have preventive maintenance programs and had rules that prevented the efficient use of maintenance labor. Bonnell also found that in one large transit system, promotions of bus maintenance personnel were based upon seniority rather than merit, acquired skill or aptitude, and he listed several instances of waste and cost increases. Since that report changes by the Federal Transit Administration (FTA) and its predecessor, the Urban Mass Transportation Administration, have addressed many of these concerns. For example, the FTA now requires transit systems to have maintenance plans for vehicles purchased with federal subsidies and to operate such vehicles for at least 12 years. Despite these changes, subsidies have been linked to early retirement of buses and investments in capital intensive inefficient transit systems (Pickrell 1992). Cromwell (1989) alludes to the less money that recipients of federal capital subsidies spend on vehicle maintenance. He found that private providers of transit services spend 45% more on maintenance per mile and devote 29% more labor hours to maintenance than do public providers. He further finds that a 10% increase in transit capital subsidies reduces vehicle maintenance by 1.6% and that this reduction is statistically significant. Hilton (1974) and Kemp et al. (1983) argue that capital grants do not encourage vehicle and facility maintenance. We account for the importance of maintenance in the decomposition by including three variables. The first is a binary variable (AGE) which takes a value of one if average fleet age is greater than or equal to 12 years and a value of a zero otherwise to account for the FTA's 12 years of vehicle use regulation. This variable also accounts for the Taubman and Rasche (1971) effects mentioned in the introduction. The second is the number of maintenance facilities owned $(M_F)$and the third is leasing versus owning maintenance facilities (M_O). These variables are expected to account for the extensiveness and effectiveness of vehicle maintenance programs and their possible effects on coordination of maintenance activities, duplication and over-employment all of which lead to inefficiencies.

"Easy money": As the discussion in the background section shows, the federal role in providing transit subsidies has been declining. In response local areas have established dedicated funding sources for their transit systems. These sources include property taxes, tolls, utility taxes and vehicle rental taxes. Some states such as North Carolina allow counties to increase their sales taxes by between 0.25 and 0.5 cent and impose special fees on rented vehicles to fund public transit systems. The availability of dedicated funding creates a continuous stream of money to be used for capital acquisition, operations and service expansion. For some transit systems, the funds from these sources make them earn after-subsidy profits, as noted earlier, with resultant service expansions that do not reflect cost minimization as the goal. Hence, dedicated funding is a source of inefficiency. We account for "easy money" by including a binary variable for availability of local dedicated sources of funding $(LOCDED)$.

Federal regulations and other variables: Since the 1980s the federal government has required transit systems to contract out portions of their operations to private sector companies. The premise is that there are cost efficiencies from private sector provision of public transit services or contracting out services to the private sector. To account for contracting the decomposition includes a binary variable (PUR) showing if or not a transit system purchases transportation from private sector sources. The FTA also requires transit systems to maintain a spare ratio of 20% of the vehicles they operate in maximum service. The rationale is to avoid resource misallocation by using the subsidies to acquire and maintain excessive fleet. This requirement is accounted for in the decomposition by a binary variable $(SPRATIO)$ that takes a value of one if the spare ratio is equal to or greater than 20% and a zero otherwise. Finally, fleet size is included in the decomposition equation to account for heterogeneity.

Data

The data for estimating the cost, share and the decomposition equations are from the 2006 U.S. National Transportation Statistics (NTS) database.[12] The sample consists of 227 single-mode bus transit systems each of which received both operating and capital subsidies and had no missing data on output and inputs. Labor is measured as hours worked, fleet size is a proxy for capital, and gallons of fuel are a proxy for all other inputs. Labor price (w) is annual total labor compensation including benefits divided by annual labor hours; fuel price (p) is total operating cost less total labor compensation divided by gallons of fuel; the price of capital (r) is yearly bus user cost[13] and following Nadiri and Schankerman (1981) capital cost rK is added to operating cost to give total cost. Thus, $C = wL + pF + rK$.

The descriptive statistics in Table 3 show that the ratios of operating subsidy to input costs are far larger than the corresponding ratios of capital subsidy to input cost. For both subsidies, this ratio is largest for fuel and smallest for labor. The mean transit system received \$11.212 million and \$2.608 million in operating and capital subsidies respectively while paying \$18.21 per hour for labor, \$8.45 per gallon for fuel,[14] and incurring capital user costs of \$44,423 per vehicle and a total cost of \$18.946 million. This transit system produced 2.959 million

Table 3: Descriptive Statistics

Variable	N	Mean	Std. Deviation	Minimum	Maximum
Total Cost ($ million)	227	18.946	29.553	0.984	276.868
Vehicle miles (million)	227	2.959	4.349	0.026	39.504
Labor wage ($)	227	18.21	58.77	6.12	894.960
Capital user cost per vehicle ($)	227	44,422.73	6,075.01	3,636.42	56,646.740
Fuel price per gallon ($)	227	8.45	9.64	3.38	99.870
Labor hours (million)	227	6.202	0.844	0.099	6.811
Fleet size	227	94	119	7	905
Gallons of fuel (million)	227	0.584	1.004	0.022	10.091
Capital subsidy ($ million)	227	2.608	4.157	0.001	30.114
Operating subsidy ($ million)	227	11.212	17.814	0.006	154.589
Ratio of operating subsidy to labor cost	227	1.155	0.234	0.001	1.750
Ratio of operating subsidy to fuel cost	227	2.667	0.744	0.003	5.180
Ratio of operating subsidy to capital cost	227	2.448	1.195	0.002	7.296
Ratio of capital subsidy to labor cost	227	0.325	0.411	0.001	2.843
Ratio of capital subsidy to capital cost	227	0.645	0.971	0.002	10.244
Ratio of capital subsidy to fuel cost	227	0.714	0.819	0.001	6.173
Ratio vehicles operated in maximum service to fleet size	227	0.723	0.153	0.103	0.995
Directly operated service	227	0.577	0.495	0	1.000
Availability of local dedicated funding source	227	0.370	0.483	0	1.000
Number of maintenance facilities	227	1.742	1.340	1.000	9.000
Proportion owning maintenance facilities	227	0.793	0.407	0	1.000
Proportion leasing maintenance facilities	227	0.035	0.186	0	1.000
Proportion leasing and owning maintenance facility	227	0.128	0.335	0	1.000

Fuel is a proxy for all non-labor and non-capital inputs. Therefore, its costs include the costs of materials, tires and all types of liquid fuels, and a portion of the cost of purchased service.

vehicle miles of service using 6.202 million hours of labor, 94 vehicles and 0.584 million gallons of fuel. 42.3% of the sampled transit systems purchased transportation services from private sector companies, 79.3% owned their maintenance facilities, 3.5% leased these facilities and 12.08% owned and leased some of them. Finally, 37% had dedicated local funding and on the average each transit system owned 1.74 maintenance facilities.

Results

Table 4 shows the results of estimating the cost and share equations for labor and fuel jointly using non-linear seemingly unrelated methods and the Marquardt optimization technique.[15] At convergence the model used 164 observations and gave coefficients of determination of 0.7590, 0.3706 and 0.3150 for cost, labor share and fuel share equations respectively. From the estimated coefficients the long run shares of labor, fuel and capital in implied cost are respectively 68.63%, 25.83% and 5.54% and the mean value of $\ln(\upsilon)$ is 0.5255 (*Std. Dev. = 0.082*). The latter result shows that total actual cost is 52.55% larger than the minimum implied cost. Alternatively, it shows that at the mean the subsidies account for a little more than a half of the total actual cost of transit systems. Using the relevant coefficients in the price elasticity of input demand equation $\vartheta_i = S_i^* + (\beta_{ii} / S_i^*) - 1$, Table 5 shows the mean values of price elasticities of input demand and the deadweight losses.[16] Very clearly, all transit inputs have inelastic demand, and in

Table 4: Estimated Coefficients

Variable	Parameter	Estimate	Std. Error	t-value	Probability
Share of operating subsidy in capital cost (H_{oK})	μ_{oK}	0.1941	0.0012	165.2000	<.0001
Share of operating subsidy in labor cost (H_{oL})	μ_{oL}	0.5631	0.0007	816.1300	<.0001
Share of operating subsidy in fuel cost (H_{oF})	μ_{oF}	0.2428	0.0010	252.9800	<.0001
Share of capital subsidy in capital cost (H_{KK})	μ_{KK}	0.4789	0.0089	54.0800	<.0001
Share of capital subsidy in labor cost (H_{KL})	μ_{KL}	0.4389	0.0073	60.0000	<.0001
Share of capital subsidy in fuel cost (H_{KF})	μ_{KF}	0.0822	0.0059	13.8700	<.0001
$\log(w^*)$	β_L	0.6863	0.0044	157.3200	<.0001
$\log(p^*)$	β_F	0.2583	0.0036	72.6600	<.0001
$\log(r^*)$	β_K	0.0554	0.0017	33.4000	<.0001
$0.5\log(w^*)\ \log(w^*)$	β_{LL}	0.0555	0.0033	17.0400	<.0001
$\log(w^*)\ \log(p^*)$	β_{LF}	-0.0453	0.0026	-17.7000	<.0001
$\log(w^*)\ \log(r^*)$	β_{LK}	-0.0102	0.0015	-7.0500	<.0001
$0.5\log(p^*)\ \log(p^*)$	β_{FF}	0.0391	0.0023	17.1600	<.0001
$\log(p^*)\ \log(r^*)$	β_{FK}	0.0061	0.0011	5.5600	<.0001
$0.5\log(r^*)\ \log(r^*)$	β_{KK}	0.0041	0.0013	3.1100	0.0022
Constant	β_o	0.7768	0.0490	15.8600	<.0001
$\ln Q$	β_Q	0.7805	0.0415	18.8000	<.0001
$0.5\ln(Q)\ln(Q)$	β_{QQ}	0.1593	0.0436	3.6600	0.0004
$\ln(Q)\ln(w^*)$	β_{LQ}	0.0022	0.0042	0.5300	0.5940
$\ln(Q)\ln(p^*)$	β_{FQ}	-0.0002	0.0034	-0.0500	0.9571
$\ln(Q)\ln(r^*)$	β_{KQ}	-0.0021	0.0017	-1.2300	0.2202

Table 5: Elasticity, Cost Share and Deadweight Loss

Variable	**N**	**Mean**	**Std**
$\ln(\upsilon)$	164	0.5255	0.0817
Wage elasticity of labor demand	164	-0.2416	0.0656
Price elasticity of fuel demand	164	-0.5756	0.0395
Price elasticity of capital demand	164	-0.8676	0.0083
Share of labor in actual total cost	164	0.6873	0.0655
Share of capital in implied cost	164	0.0531	0.0215
Share of fuel in actual total cost	164	0.2593	0.0516
Share of labor in implied cost	164	0.6749	0.0771
Share of capital in actual total cost	164	0.0583	0.0140
Share of fuel in implied cost	164	0.2668	0.0637
Share of deadweight loss in actual total cost	164	0.0683	0.0216
Share of deadweight loss from labor in cost	164	0.0374	0.0149
Share of deadweight loss from fuel in cost	164	0.0253	0.0085
Share of deadweight loss from capital in cost	164	0.0056	0.0032
Total deadweight loss ($)	164	861,081.77	1,435,368.63
Deadweight loss from labor demand ($)	164	439,838.54	722,008.38
Deadweight loss from fuel demand ($)	164	336,147.28	566,079.15
Deadweight loss from capital demand ($)	164	85.095.95	169,844.13
Operating Subsidies Only			
$\ln(\upsilon)$	215	0.4857	0.0696
Share of deadweight loss in total cost	215	0.0566	0.0170
Total deadweight Loss ($)	215	780,137.88	1,232,145.46
Share of deadweight loss from labor in cost	215	0.0305	0.0125
Share of deadweight loss from fuel in cost	215	0.0225	0.0071
Share of deadweight loss from capital in cost	215	0.0036	0.0024
Deadweight loss from labor demand ($)	215	385,409	605,925.40
Deadweight loss from fuel demand ($)	215	328,214.03	522,875.22
Deadweight loss from capital demand ($)	215	66,514.33	133,069.33
Capital Subsidies Only			
$\ln(\upsilon)$	220	0.0999	0.0881
Share of deadweight loss in total cost	220	0.0043	0.0071
Total deadweight loss ($)	220	50,287.10	100,896.42
Share of deadweight loss from labor in cost	220	0.0023	0.0045
Share of deadweight loss from fuel in cost	220	0.0004	0.0008
Share of deadweight loss from capital in cost	220	0.0017	0.0023
Deadweight loss from labor demand ($)	220	19,784.44	39,144.20
Deadweight loss from fuel demand ($)	220	4,047.22	8,251.73
Deadweight loss from capital demand ($)	220	26,455.45	58,124.55

*Excludes three transit systems whose elasticities of input demand were positive.

absolute terms the elasticities of input demand are relatively large for capital (0.8676) and fuel (0.5756) than they are for labor (0.2416). The subsidies too reduce the share of labor in cost and increase the share of fuel while leaving that of capital almost unchanged.

The mean deadweight loss for the 164 transit systems is $0.861 million, most of which comes from misusing some of the subsidies going to labor ($0.440 million) possibly by not matching employment to skills, followed by those going to fuel ($0.336 million) and capital ($0.085 million). These results appear surprising because labor demand being relatively less sensitive to changes in price than the other inputs should have the lowest deadweight loss. That, it does not, is because labor's share in cost is the largest of the three inputs, and the larger the cost share of an input the larger is the deadweight loss. It follows from these results that the share of an input in cost has a larger impact on deadweight loss than the price elasticity of input demand. When deadweight loss is expressed as a ratio of total cost, its mean value of 6.83% decomposes into 3.74%, 2.53% and 0.56% respectively from misusing some of the subsidies going to labor, fuel and capital.

Also, Table 5 shows the results when either capital subsidy or operating subsidy is a zero. When capital subsidy is zero, transit systems receive only operating subsidy and we are able to calculate deadweight losses for 215 of them using the estimated coefficients. Here, total actual cost exceeds the minimum implied cost by 48.57% and the share of deadweight loss in total actual cost is 5.66% or $0.78 million on the average. This deadweight loss decomposes into 3.05%, 2.25% and 0.36% respectively from misusing some of the subsidies going to labor, fuel and capital. When operating subsidy is zero, transit systems receive only capital subsidy and we are able to calculate deadweight losses for 220 of them. In this case total actual cost exceeds the minimum implied cost by a mere 9.99% and deadweight loss is only $50,287 or 0.44% of total actual cost on the average. This deadweight loss as a share in cost decomposes into 0.23%, 0.17% and 0.04% respectively from misusing some of the subsidies going to labor, capital, and fuel. Comparing these results, large misuse of some of operating subsidy is responsible for the deadweight loss while misuse of some capital subsidy adds very little to deadweight loss.

Additionally, we calculated the ratio of actual to optimal subsidies and found that no transit system received more than its optimal amount of each subsidy. For operating subsidies, the mean of this ratio is 0.1599 (*Std. Dev. = 0.0696*) and for capital subsidies it is 0.1389 (*Std. Dev. = 0.1206*). Therefore, the deadweight losses are not because the transit systems received

Table 6: Sources of Deadweight Loss

Variable	**Estimate**	**Std. Error**	**t**	**Probability**
Intercept	-865,534.00	212,446.00	-4.07	<.0001
Extensiveness of maintenance				
AGE: Years of use regulation	-115,807.00	325,693.00	-0.36	0.7227
M_o : Does not own of maintenance facility (Yes = 1, No = 0)	-234,273.00	128,223.00	-1.83	0.0697
M_F : Number of maintenance facilities used	229,716.00	47,205.00	4.87	<.0001
$SPRATIO$: Spare ratio regulation	181,915.00	115,008.00	1.58	0.1158
Incentive tier				
PM : Passenger miles	0.0228	0.0030	7.55	<.0001
Federal labor protection				
L/K : Section 13(C) effect, i.e., employees per vehicle	141,493.00	46,954.00	3.01	0.0030
"Easy money"				
$LOCDED$: No dedicated local funding (Yes = 1, No = 0)	-228,323.00	93,181.00	-2.45	0.0154
Other variables				
K : Fleet size	4,222.90	718.87	5.87	<.0001
PUR: Purchased transportation (Yes = 1, No = 0)	33,473.00	100,427.00	0.33	0.7394

excess subsidies but the presence of waste in using some of the subsidies, particularly operating subsidies.

Finally, Table 6 shows the results of estimating the decomposition equation. This equation explains 86.53% of the variation in deadweight loss, and all the variables have statistically significant coefficients except three. These are purchased transportation, year-of-vehicle-use regulation and spare ratio regulation. Examining the coefficients, those of transit systems which do not directly own their maintenance facilities and the absence of "easy money" are statistically significant and negative. The respective coefficients of these variables show that they are associated with $234,273 and $228,323 reductions in deadweight loss. The other estimated coefficients are positive and their variables are associated with increases in deadweight losses. From these latter coefficients, the marginal effect of the labor-capital ratio, our indicator of Section 13(C) effect, is an increase of $141,493 in deadweight loss and the marginal effect of the number of maintenance facilities is an increase of $229,716 in deadweight loss. Comparatively, the marginal effects of fleet size and passenger miles (i.e., the incentive tier) are increases in deadweight loss of $4,222.90 and $0.0228 respectively.

Conclusion

The purpose of this paper is to calculate the deadweight losses from the operating and capital subsidies received by US public transit systems. The calculation extends the works of Tullock (1998). It uses data for 227 single-mode bus transit systems and estimates a neoclassical cost function that does not assume cost minimization. The results show that deadweight loss is $0.861 million on the average largely due to $0.440 million, $0.336 million and $0.0851 million from misusing some of the subsidies going to labor, fuel and capital demand respectively. Overall, deadweight loss accounts for 6.83% of the total cost of the average public transit system. The decomposition of this loss shows that on the average $0.78 million of operating subsidy is misused and $0.050 million of capital subsidy is misused. Thus, 90.59% of the deadweight loss comes from transit systems misusing some of their operating subsidies. A further decomposition by regression shows that the factors which are positively associated with deadweight loss are the extensiveness of maintenance operations, Section 5333(b) labor protection effect (i.e., the effect of Section 13(c)), the effect of the incentive tier of the federal formula grant and fleet size. Two factors negatively associated with deadweight loss are leasing instead of directly owning maintenance facilities and the absence of "easy money" in the form of not having local dedicated funding sources. The latter result suggests that funding agencies should ensure that transit systems with local dedicated funding sources pursue cost minimization objectives. Also, from the results, deadweight loss from operating and capital subsidies can be reduced by changing the formula for the incentive tier of the Section 5307 formula grants possibly by removing operating cost as a denominator thereby ridding it of its inefficiency effect, and revising the federal labor protection clause imposed by Section 5333(b) of the FTA Act by lobbying for congressional action to reduce the years over which compensation should be paid to those whose jobs are adversely affected by federal subsidies.

End Notes

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[1] See federaltimes.com at http://www.federaltimes.com/index.php?S=2718985 (accessed 3/23/2009). This site reports that "after investigating just three days of sales on the internet auction site eBay, GAO identified 20 federal employees who had illegally sold more than $21,000 worth of transit benefits during the past two years."

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[2] Federal regulations do not allow using subsidies and other monies from federal sources to influence how subsidies are allocated such as hiring lobbyists. But, transit systems can use their employees who work at least 130 days for them for such purposes.

[3] These are paid to U.S steamship yards that are constructing subsidized ships to prevent them from losing their businesses to foreign shipyards.

[4] These are paid to US flagship owners for the incremental costs of hiring crews who are US citizens.

[5] The choice of output does not affect the results.

[6] Throughout this paper the terms “implied”, “misperceived” and “after-subsidy” are used interchangeably.

[7] Though we use labor in this discussion other inputs can also be used. The choice of an input does not affect the equations derived.

[8] In specifying this equation we do not include such characteristics of operating environment as population and population density and route miles because their coefficients were not statistically significant in an initial specification of the model that included them.

[9] The FTA suggests a spare ratio of 20% of the vehicles operated in maximum service.

[10] Although we could have used passenger miles squared over operating cost, we opt for this approach because the total actual cost used in calculating deadweight loss includes operating cost.

[11] These findings are also contained in: Comptroller General 1981. Report to the Congress of the United States: Soaring transit subsidies must be controlled. United States General Accounting Office, Washington DC.

[12] These transit systems operate regular buses, vanpools, express bus services and demand responsive services.

[13] Capital cost is calculated as $rK = Kr_K\left(R + d\right)e^{-d(z)}$ where, K is fleet size, r_K is the weighted average price of a new public transit bus in 2006 and z is the weighted average fleet age. R is the average prime rate for 2006, d is a straight line rate of depreciation assuming a bus useful life of 20 years.

[14] Again, the calculation of fuel price is all non-labor operating cost divided by gallons of fuel so it is large.

[15] To estimate the equations the expression $(1-\mu_{oL}H_{oL}-\mu_{KL}H_{KL})^{-1}$ in the actual cost and labor share equations was expanded up to first order to obtain $(1+\mu_{oL}H_{oL}+\mu_{KL}H_{KL})$. The same expansion was done for similar terms in the capital and fuel share equations. Notice that because μ and H take values between zero and one the quadratic and higher order terms in this expansion add very little to the cost and input shares.

[16] This equation can be derived by solving Eq. (15) for input quantity and differentiating the logarithm of the result with respect to the logarithm of implied price.

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APPENDIX A

To determine if these optimal subsidies are minimum or maximum we differentiate Eq. (9) with respect to operating subsidies. That differentiation yields,

$$(A.1) \qquad \frac{\partial^2 (DWL)}{\partial A_o^2} = \frac{\eta_L \mu_{oL} \left[\eta_L (1-2h) \frac{\partial h}{\partial A_o} - h(\eta_L h + 2 w_o L) \frac{\partial g}{\partial A_o} \right]}{g}$$

$$where\ g = 1 + \eta_L \left(\mu_{oL} H_{oL} + \mu_{KL} H_{KL} \right) \quad and \quad h = \mu_{oL} A_o + \mu_{KL} A_K$$

Now, $\partial h / \partial A_o = \mu_{oL},$ $\quad \partial g / \partial A_o = \eta_{?} \mu_{OL} / w_o L$, Substituting them into (A.1) gives

$$(A.2) \qquad \frac{\partial^2 (DWL)}{\partial A_o^2} = \frac{\eta_L^2 \mu_{oL}^2 \left[1 - 4h - h^2 \mu_{oL} / w_o L \right]}{g}$$

Further, substituting the optimal value of operating subsidy into A.2 gives a negative value for the second order partial derivative as can be seen by inspection. Therefore, the optimal subsidies calculated are the maximum subsidies.