Un corte en las transferencias corrientes puede aumentar o disminuir el ahorro. El ahorro cae si la política afecta el ingreso corriente, de manera tal que compensa dos efectos que trabajan en la dirección contraria: la reasignación de recursos de inversión a ahorro y la caída en el producto futuro debido a la menor productividad de la mano de obra e inversión.

Usando (21a), (22b) y la definición de arriba, se resuelve el sistema (39), obteniendo:

$$dS_1^L = -1$$

$$dS_2 = \frac{ac(1-t)\Sigma - (1+r)\left[a(1-c)(1-I_L\xi') + t\Sigma b_r\right]}{(1+r)B_r + ac}$$

$$dr = \frac{(1+r)(1-c)(1-I_L\xi') - ct\Sigma}{(1+r)B_r + ac}$$

Estos resultados se utilizan para obtener (40a) y (40b) en el texto.

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NEW FINDINGS IN THE THEORY OF OPTIMAL CONGESTION TAXES, WITH AN APPLICATION TO ROAD TRANSPORTATION

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Abstract:

It is generally assumed that optimal taxes in the case of congestion tend to reduce output. However, in those cases where congestion is worst, the effect of the tax may in fact be to **increase** *output. Furthermore, an increase in demand leads to a* **fall** *in output in those cases. Also, the optimal tax may then appear to be a subsidy, and has led some to conclude that the optimal tax formula is unsatisfactory. It is satisfactory, once properly interpreted. Finally, the tax may* **raise** *after-tax welfare of resource users.*

I. Introduction

It is now generally recognized in the literature that the competitive use of a common property resource results in an inefficient allocation of resources due to negative externalities which lead to a difference between private and social returns or costs (*e.g.*, Winston (1985) on transportation, and Gordon (1954) and Scott (1955) on fisheries).

These externalities are of two types: 1) Contemporaneous externalities due to congestion, and 2) Dynamic externalities due to the impact of current actions of future costs and revenues. Issues such as road deterioration and expansion or such as growth and depletion of fish stock have been examined in a number of papers incorporating dynamic externalities. These papers have derived optimal pricing and fishing rules in the case of fisheries (*e.g.*, Smith, 1968) and optimal pricing and investment rules in the case of roads (*e.g.*, Mohring and Harwitz, 1962; Mohring, 1970; Newbery, 1986; Small and Winston, 1986, and Vickery, 1969).

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This paper does not deal with dynamic issues. Rather, we focus here on congestion because we believe that some confusion exists with respect to the concept of congestion and the implications regarding the impact of policies designed to correct it.

Studies on congestion (*e.g.*, Gordon, Mohring, 1976; Newbery, 1987) have determined that the optimal output tax equals the difference between the marginal (social) cost and the average (private) cost, and that the impact of the tax is to reduce output. Surprisingly, what has not been realized is that in those cases where congestion is worst and thus when the optimal tax is actually most important in terms of increasing the efficiency of resource allocation, the effect of that may in fact be to increase output. Furthermore, an increase in demand will lead to a fall in output in those cases. And when producers also consume the product (as in road travel), the tax may raise consumer after-tax welfare. This occurs when there is a reversal in the relation between the quantity of input and output. This has been found empirically in the case of road transportation, but the implications for the impact of taxation on output have not been worked out.

Moreover, in those cases, the optimal tax may appear to be a subsidy. This has led Newbery (1987) to conclude that the optimal tax formula is unsatisfactory. In fact, the solution makes perfect sense once it is properly interpreted.

The positive effect of the optimal tax on output is likely to apply to a large number of cases, including shopping, road and air travel, to the case in international trade known as "immiserizing growth", and to large cities. The rest of the paper is organized as follows: Section II develops the conceptual framework and its implications. Section III presents an application to road transport where we clarify the nature of the cost of travel function and of optimal taxation. Section IV concludes.

II. Conceptual Framework and Implications

As standard textbooks in economics have taught us, when some factor of production is fixed, the marginal product of the variable factor will diminish eventually. This leads to a wedge between the average product AP of the variable factor L, and its marginal product MP, with AP > MP (though when L is small, MP may be larger or equal to AP).

This wedge does not by itself lead to an inefficient allocation of resources as long as the fixed factor is owned and the owner maximizes competitive profits. In that case, the variable factor L will be used up to the point $L = L_1$, where the value of its marginal product VMP equals its price W (VMP = W), which is the Pareto efficient solution. The inefficiency arises when the fixed factor is not owned. In that case, the returns to the variable factor exhaust the entire product, and the value of the fixed factor is driven to zero. Each unit of the variable factor obtains the value of its average product VAP. Variable factors L will enter the activity up to the point $L = L_0$ where VAP = W, and since VAP > VMP, the quantity of variable factors used is larger in the case where the fixed factor is a common property resource ($L_0 > L_1$). At $L = L_0$, VMP < W = VAP. In the words, factors obtain VAP while their marginal contribution VMP is lower.

The average product AP of the last unit of the variable factor is larger than MP because part of its average return is obtained by lowering the average return of the intramarginal units. This congestion externality is not internalized when the fixed factor is not owned (or when its use is not taxed) and is the basis of the inefficiency.

In order to eliminate the inefficiency, two solutions are possible: 1) assigning the property rights to the resource (and ensuring competitive behavior), or 2) charging and optimal tax for the use of that resource, where the optimal *input* tax is VAP - VMP.

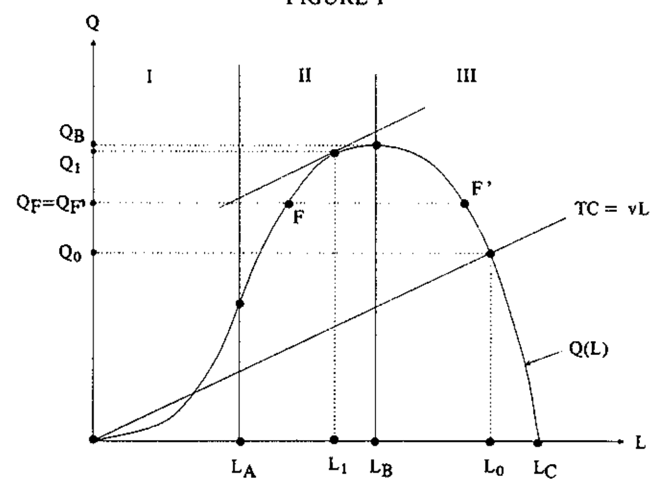
Both policies have the same impact on the allocation of resources, *i.e.*, the use of variable factors L falls from L_0 to L_1 (to the point where VMP = W) since the net return to those factors falls from VAP to VMP (because of the tax or because the owner of the fixed factor pays variable factors their VMP). Profits from the resource rise from zero to (VAP −W). L_1 and the value of the resource rises from zero to the present value of a flow of such profits.

The literature on common property resources then concludes that output Q = Q(L) also falls when variable inputs are used optimally, *i.e.*, that $Q_1 = Q(L_1) < Q_0 = Q(L_0)$ (*e.g.*, Gordon, Mohring, 1976). However, there is no *a priori* reason to expect this to be case. The conclusion that output falls is due to a confusion between a flow concept (output per unit of time) and a stock concept (the number of variable inputs used at a moment in time). Congestion is essentially a function of the number of inputs used at a moment in time rather than of the level of output obtained per unit of time, something that has not generally been appreciated, especially in the transportation literature.

Simply put, since the relation between output Q and variable inputs L is not monotonic, a decrease in L may lead to an increase in Q. This will not occur under normal competitive conditions. However, it could occur in the case of a common property resource because of the negative congestion externality. Figure 1 illustrates this point. It shows the relationship between output Q per unit of time and the level of variable inputs L, as well as total cost vL, where v is the relative price of L measured in units of Q (v = W/P, with P = price of Q). We assume for simplicity that W(P) is constant and does not change with L(Q).

In Zone I ($L < L_A$) the marginal product MP is positive and larger than the average product AP, *i.e.*, 0 < AP < MP. Zone II ($L_A < L < L_B$) is the area where 0 < MP < AP In Zone III ($L > L_B$) MP is negative or Q is falling, *i.e.*, MP < 0 < AP. In terms of marginal cost MC = W/MP, in Zone II, MC > 0 and MC > AC = W/AP, the average cost. MC = ∞ at $L = L_B$, and MC < 0 in Zone III (*i.e.*, output can be increased by reducing inputs and costs in Zone III).

FIGURE 1



As is well known, when the fixed factor is owned a competitive firm maximizing profits will always choose L in Zone II, *i.e.*, where $L_A < L < L_B$ (unless v is so high that variable costs are larger than revenue at any positive L, in which case L = 0). For instance, in Figure 1, the competitive solution is at $L = L_1$ where MP = v = W/P, or VMP = W

However, in the case of a common property resource, VAP = W or PQ/L = W, *i.e.*, L is at a point where revenue per unit of L equals cost per unit of L, so that profits are zero. This can occur in Zone II but it can also occur in Zone III, depending on v. (It could also occur in Zone I but is unstable). As drawn in Figure 1, the use of factors in that case is $L = L_0$ and occurs in Zone III. The optimum *input* tax measured in units of Q is the difference between the average product of Q_1/L_1 and v, and total tax revenue is $Q_1 - vL_1$. The inefficiency loss measured in units of Q is also $Q_1 - vL_1$, and has two components: the loss in output $Q_1 - Q_0$, and the increase in costs $Q_0 - vL_1$.

As drawn in Figure 1, output at the optimum $Q_1 = Q(L_1)$ is *larger* than output under the common property solution $Q_0 = Q(L_0)$, even though $L_0 > L_1$. This is due to the fact that MP < 0 between L_0 and L_B and dominates the positive MP between L_B and L_1 Output Q_F at point F equals output Q_F, at F', and AV at F' equals MC at F. If $Q_0 > Q_F$, then $Q_1 < Q_0$. If $Q_0 = Q_F$, then $Q_1 = Q_0 = Q_F$. If $Q_0 < Q_F$, then $Q_1 > Q_0$. Moreover, an increase in demand raises price P and therefore lowers v. This leads to an increase in L and may lead to a fall in output Q in the absence of the optimum tax (when the common property solution is in or close to Zone III).

In the absence of congestion of other externalities a tax will increase marginal cost and will lead to a reduction in output. However, in the case of a negative externality, there are two opposing effects. A tax leads to a reduction in the use of inputs but it also leads to a reduction in the negative externality, so that the impact on output is ambiguous and depends on which effect dominates. Output per unit of input AP is positive while the externality MP-AP is negative. If, as drawn in Figure 1, the latter dominates, then reducing input use through the optimum tax leads to an increase in output.

Inputs in a congested area such as cars on a road, shoppers in a supermarket or department store, or such as fishing vessels or fishermen on a lake or river, can be thought of as separate firms in an industry characterized by diseconomies external to the firms but internal to the industry. Taxation reduces the number of firms but also reduces the diseconomy, and the impact on industry output depends on which effect dominates. For instance, reducing the number of supermarket shoppers on a Saturday morning (say, by charging an entry fee) may very well reduce congestion to the point where total sales actually increase.

In trade theory, for instance, this applies to the case of immiserizing growth (Bhagwati, 1958), where an increase in the quantity of exports may lead to a fall in revenue because of a fall in price due to monopoly power in the world market. The fall in revenue occurs if marginal revenue is negative, which can only happen if the optimal tax is not applied. In terms of Figure 1, with revenue on the vertical axis and quantity of exports on the horizontal axis, immiserizing growth occurs in Zone III.

Competitive exporting firms in an industry with monopoly power on the world market have a "common property resource" which is external to the firms but internal to the industry. That resource is the monopoly power whose value, when used optimally, is the present value of a flow equal to the difference between monopoly profits and competitive profits. In the absence of optimal export taxation, the competitive firms will drive the value of that resource to zero since none of them can appropriate the resource. Thus, the case of immiserizing growth can be thought of as a special case of a common property resource which it not used optimally. As mentioned earlier, an alternative to optimal taxation in that case would be to assign the property rights to the resource. A government agency or a private firm could be given exclusive rights to export the product, with the obligation to buy from domestic producers at a competitive price.

The inverse relation (found in Zone III) between input L and output Q in the case of a congested common property resource may occur in a large number of cases. For instance, it might occur in the cases of fisheries, underground water, petroleum and natural gas, where property rights are not well defined because the physical boundary of the natural resource is unknown or its location varies. If the physical boundaries of the resource could be precisely identified or if those boundaries were stable, the resource could be divided among independent productive units without significant congestion externalities. This is the case for such natural resources as forests[1], coal and other mineral resources.

However, the phenomenon described above is more likely to occur in cases such as large cities, road transportation, shopping, ports, air travel, visits to a zoo, amusement park, museum, public pool or beach, and panic escape from, say, a structure on fire, where space is an essential input in the production process. In those cases, an increase in the number of "users" may raise the amount of time needed by each in order to complete the activity or may reduce the quality of the activity or both, so that total output or value of output obtained per unit of time may fall as the number of users increases.

III. Road Transportation

We clarify, under very general assumptions, the relation between speed S, road output per unit of time Q and the number of cars (inputs) on a road at a moment in time L. We then derive the optimal congestion tax and the impact of the tax on output Q and on consumer welfare, *i.e.*, on the welfare of the road users. We show that when congestion is high it is in the interest of the road users to be taxed, even if they receive none of the tax proceeds.

We define the output Q per unit of time of a road of given length (and other characteristics) as the volume or flow of cars passing through that road per unit of time, or in other words, as the number of trips completed per unit of time. The approach taken in the literature (*e.g.*, Newbery, 1987; Mohring, 1976; Winston s survey, 1985) in order to determine the optimal congestion tax usually starts by postulating a relationship between speed S and flow of cars Q per unit of time:

(1) $S = f(Q)$

The private unit travel cost AC for a typical car has two components, the vehicle operating costs and the time costs. Assume, for simplicity, that the operating costs are constant and equal to a. Then,

(2) $AC = a + Wt,$

where W = value of time of the vehicle occupants and t = length of time needed to complete a trip through that road.

The length of time t needed to complete a trip is

(3) $t = 1/S,$

where speed S is defined in units of "lengths of road per unit of time". Thus,

(4) $AC = a + W/S$

The total cost TC of a flow Q is

(5) $TC \equiv Q.AC$

The increase in the total cost due to an increase in the flow Q is:

(6) $$MC \equiv dTC/dQ = AC + Q.\frac{dAC}{dQ} = AC + Q\left(\frac{-f'w}{S^2}\right),$$

where $Q\frac{dAC}{dQ}$ is the congestion externality imposed on the other cars.

A demand for road trips is also generally postulated in the literature as

(7) $Q_D = Q_D(P),\ Q'_D < 0,$

where P = the marginal value of a trip on that road.

Supply is given by the AC (which is the private marginal cost) and equilibrium is at a number of trips Q_0 where demand equals supply, *i.e.*, where P = AC. This is shown in Figure 3 where the demand and AC curves are given by D_0 and by C_0C_1, respectively.

The welfare maximizing solution is where the (social) marginal cost equals marginal value, or MC = P. Assuming $f' < 0$, MC > AC, and the optimum toll MC – AC > 0. This is shown, among others, in Winston's survey. After imposition of the optimum toll, equilibrium is at Q_1, with $Q_1 < Q_0$ (see Figure 3). Thus, studies in the literature conclude that imposing the optimum toll leads to a reduction in the volumen of cars from Q_0 to Q_1

On the other hand, a number of empirical studies have estimated the relationship between volume or output Q and speed S (Wohl and Martin, 1967, Drew 1968, Pignataro, 1973). The relationship S = f(Q) (or highway congestion function) has been found to be as depicted in Figure 2. Its slope changes from negative to positive at S_B where volume $Q = Q_B$ reaches a maximum. It goes through the origin since at S = 0, Q = 0. The exact shape depends on the type of road (number of lanes, etc.) and on the speed limit. Figure 2 also shows the demand curves for travel D, D_1 and D_2. They exhibit a positive slope since travel cost is inversely related to speed of travel S (equation 4).

The empirical relationship S(Q) shown in Figure 2 does not correspond to the assumption that $dS/dQ = f' < 0$ for all values of S. That negative relation between S and Q holds for $S > S_B$. However, for $S < S_b$, the relationship is positive. The empirical studies mentioned above have found that for urban roads the turning point (Q_B, S_B) in the S(Q) function (where $Q = Q_B$ is at a maximum), occurs at a speed S_B which is between 25 and 40 miles per hour. For two-way urban streets in Pennsylvania cities in 1961, Coleman estimated the following relationship: $Q/Q_B = -1.9 + 1.02t - 0.09t^2$, where time t is measured in minutes per mile. Maximum volume $Q = Q_B$ occurs at t = 5.67 or at S_b = 10.6 miles per hour.

What is the explanation for the shape of the S(Q) function? At $Q = Q_1$, there are two possible speeds: S_1 and S_2. The number of cars Q accessing the road can be thought

FIGURE 2

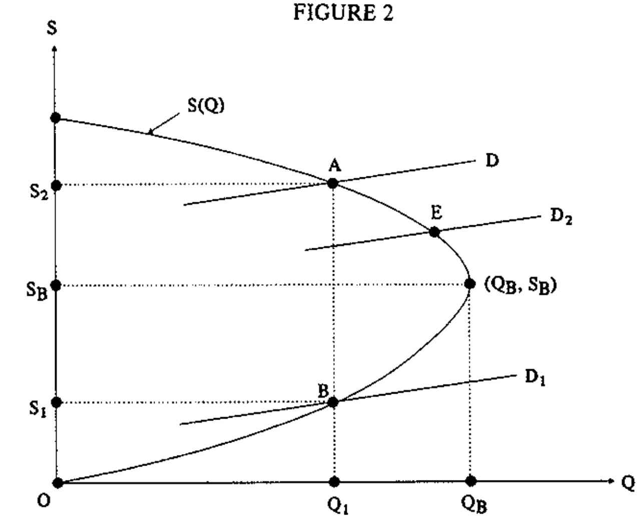
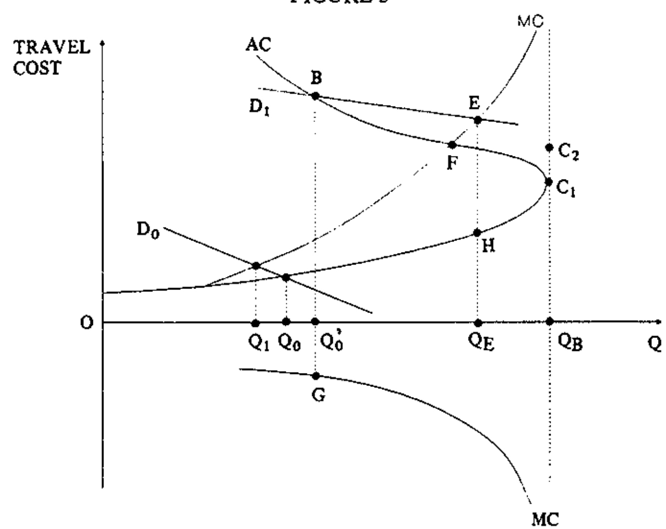


FIGURE 3



of as the quantity demanded, and the number of cars q leaving the road as the quantity of travel 'supplied" by the road. Say demand is D and we are at point A in Figure 2, a steady state situation at spped S_2 with $Q_1 = q_1$. Then, the number of cars on the road at any moment of time is a constant $L = L_2$, with the number of cars at any moment of time t_0 being

(8) $L_{t_0} = L_0 + \int_0^{t_0} (Q_{s'} - q_s)\, ds$

where L_0 is the number of cars at time t = 0 and s is a variable of integration.

Assume now that suddenly demand increases from D to D_1 so that a larger volume of cars $Q > Q_1$ is accesing the road per unit of time. Then the number of cars on the road will rise to $L > L_2$, congestion will increase and speed will fall to $S < S_2$. The volume of cars q leaving the road will not increase as much as Q because of the fall in speed. As long as Q > q, L continues to rise and speed falls. When the number of cars on the road passes a certain level L_B, congestion reaches such a level that the volume of cars leaving the road falls. As speed falls, AC rises and the quantity demanded Q falls. This process continues until the excess-demand (Q-q) is eliminated. As drawn in Figure 2, this occurs at point B where $S = S_1$ and $Q = Q_1$[2]. In the new equilibrium, the number of cars on the road is $L_1 > L_B > L_2$.

Thus, the volume Q_1 can be associated with two different speeds, S_1 and S_2, each of which is associated with a number of cars on the road, L_1 and L_2, respectively. Thus $S_1 = S(L_1)$ and $S_2 = S(L_2)$. Since speed does not depend uniquely on volume Q, it follows that volume is not the adequate variable to be used in order to determine speed and measure the level of congestion and externality.

We argue that speed is determined by the number of cars on the road at any moment of time L, *i.e.*,

(9) $S = S(L),\ S' \leqslant 0.$

Thus speed depends on the stock of cars L on the road at any moment in time, and *not* on the flow of cars Q passing through that road per unit of time. Consequently, costs also depend on L and not on Q (see equation 4).

In steady state, *i.e.*, where $\dot{L} = Q - q = 0$ ($\dot{L}$ = time derivative of L), volume Q is equal to

(10) $Q = L/t$

where t is the length of time needed to complete a trip on that road, and from equation (3), we have

(11) $Q = L.S,$

and speed S is thus the steady-state average product Q/L, measured in lengths of road per unit of time[3].

Define $\epsilon \equiv -$ dlogS/dlogL as the absolute value of the elasticity of S with respect to L. Equation (11) implies that

(12) $d\log Q/d\log L = 1 - \epsilon.$

When $S > S_B$ in Figure 2, an increase in L leads to a fall in S and an increase in Q, *i.e.*, $\epsilon < 1$. At $L = L_B$, $S = S_B$, $Q = Q_B$ and dQ/dL = 0, *i.e.*, $\epsilon = 1$. For $L > L_B$, $S < S_B$ and an increase in L results in a fall in Q(d_1/dL < 0), *i.e.*, $\epsilon > 1$. In other words, when $L > L_B$, an increase in L leads to a fall in speed S which is proportionately larger than the increase in L, so that the steady-state volume of cars Q passing through that road per unit of time falls.

The relation between Q and L is shown in Figure 1, where Q is at a maximum at Q_B where $L = L_B$, *i.e.*, where $\epsilon = 1$. As L increases beyond L_B, output Q falls, *i.e.*, the marginal product of an additional car on the road is negative because the negative externality (*i.e.*, the fall in the speed for all cars resulting in a lower volume of travel Q for the cars already on the road) dominates the private (average) contribution made by the additional car.

It is interesting to note that when $L > L_B$ (for $S < S_B$), a rise in demand for travel results in a fall in the equilibrium volume of travel Q. This can be seen from Figure 2 where the demand curve D_1 intersects S(Q) from above (from left to right). D_1 cannot intersect S(Q) from below because it would then intersect the horizontal axis, implying positive demand at an infinite cost (at S = 0, AC = ∞). Thus, an increase in demand results in a fall in output.

We can now show that an optimal toll may lead to an increase in the output Q of the even though the number of cars L falls. An optimal toll which leads to a fall in L may in fact lead in the new steady state to an increase in Q if before the toll was imposed $\epsilon > 1$, *i.e.*, $S < S_B$ and $L > L_B$. In terms of Figure 2, it implies that we are at, say point B in the pre-toll case, and after the toll is imposed, D_1 falls to D_2 (the demand net of the congestion toll), and equilibrium is at point W with $Q > Q_1$. In terms of Figure 1, it implies that after the toll, we move from a point such as (Q_0, L_0) to point (Q_1, L_1).

Equation (6) indicates that the optimal toll T is

(13) $T = MC - AC = Q\left(\frac{-f'w}{S^2}\right),$

where $f' \equiv dS/dQ$.

For $L > L_B$ $S < S_B$, $Q < Q_B$ and $f' > 0$ (see Figure 2). That implies that $T < 0$, *i.e.*, the optimal tax is a subsidy in the upward-sloping part of the S(Q) curve. Newbery (1987) states that this result is absurd since the externality is negative and largest in the upward-sloping portion of the S(Q) curve. He concludes that the solution for the optimal toll given by equation (13) is unsatisfactory[4].

In fact, the solution makes perfect sense once it is recognized that speed and the congestion externality depend on the number of cars L on the road at a moment in time and not on the volume of cars Q per unit of time. Equation (13) indicates that in the upward-sloping portion of S(Q), travel Q should be subsidized in order to raise it and move out of that inefficient area. However, in that portion of the S(Q) curve, dQ/dL < 0, *i.e.*, in order to increase Q, L must fall. Consequently, equation (13) implies that L must be taxed, *i.e.*, a tax must be imposed on the number of cars on the road in order to reduce it and thus to increase Q. On the other hand, in the downward-sloping portion of the S(Q) curve, $f' < 0$, and $T > 0$, *i.e.*, Q is taxed, and since dQ/dL > 0, that implies a tax on L. Thus, in both cases, L is taxed and will fall.

From equations (13) and (9),

(14) $T = \frac{Q(-S'w/S^2)}{dQ/dL} \gtrless 0 <\!\!-\!\!> dQ/dL \gtrless 0,$

and equation (14) shows that the sign of T equals that of dQ/dL.

After the optimal toll es imposed, the solution (which maximizes welfare) cannot be in the upward-sloping portion of the S(Q) curve, because in that portion, dQ/dL < 0, so that L can be reduced with a reduction in costs and an increase in output Q, *i.e.*, welfare can be increased in that portion. Consequently, at the optimum, $T > 0$.

This is shown in Figure 3, where AC and MC are depicted as functions of Q. Speed depends on L, so that AC also depends on L. (From equations (4) and (9), $AC = a + W/S(L)$). However, since demand is for road trips Q, AC and MC must be expressed in units of Q to solve for the pre-toll and post-toll equilibrium. Figure 3 differs from the traditional figures used, where AC and MC rise with Q (*e.g.*, Mohring, 1976, p. 19), in that it takes into account the upward-sloping portion of the S(Q) curve shown in Figure 2.

Since $S' < 0$, AC increases with L. For $L < L_B$, $dQ/dL/ > 0$, so that AC increases with Q. At $L = L_B$, Q reaches a maximum Q_B. For $L > L_B$, $dQ/dL < 0$, so that AC falls with Q. Thus, AC(Q) bends backward for $L > L_B$ (and $S < S_B$). The portion of the AC curve between points C_0 and C_1 in Figure 3 corresponds to the downward-sloping portion of the S(Q) curve where $dQ/dL > 0$. The MC corresponding to that portion of the AC curve is positive and larger than AC, as can be seen from equation (6) (since $f' < 0$ in that portion of the S(Q) curve). If demand is given by D_0, then equilibrium is at $Q = Q_0$, and the optimum is at $Q = Q_1$.

For $L > L_B$, the AC curve slopes back. At $L = L_B$, $Q = Q_B$ and $dQ/dL = 0$ ($\epsilon = 1$). Consequently,

$$MC = \frac{dTC}{dQ} = \frac{dTC}{dL}\frac{dL}{dQ} = \infty \text{ at } Q = Q_B. \text{ For } L > L_B,\ dQ/dL < 0,$$

and thus $MC < 0$.

This also shown in Figure 3, where the nagative portion of the MC curve corresponds to the backward-bending portion of the AC curve. The optimum can never be on that portion of the cost curves since the same output Q can be obtained at a lower average (and therefore lower total) cost.

In the case of a common property resource, the AC curve is the supply curve. We are thus in the presence of a backward-bending supply curve. However, in contrast with the labor supply curve where optimum may be on the backward-bending portion, such a solution is inefficient in the case of a common property resource.

Else (1981) argued that speed depends on L. However, he did not realize the implications for the impact of optimal taxation on travel volume Q. He presents a diagram similar to that of Figure 3. However, he assumes that at Q_B, MC is finite and then bends backward but remains positive. The MC curve he draws has the same shape as the AC curve, but higher, with MC intersecting the Q_B line at a point such as C_2 (see Figure 3). He then concludes that the optimum could be on the backward-bending portion of the cost curves. As discussed above, welfare is not maximized on that portion of the cost curves[5]

When demand for travel is given by D_1 in Figure 3, equilibrium is at point B with $Q = Q_0$, and $MC < 0$ (point G). The optimum is at point E, where $Q = Q_E > Q'_0$. The demand net of the congestion toll (D_2 in Figure 2) intersects the AC curve in point H Thus, imposition of the optimum toll may very well lead to an increase in output or number of trips Q per unit of time. However, if demand were below the demand curve going through point F, then optimum output would be below equilibrium output[6].

The welfare gained from imposing the optimum tax when demand is D_1 has three components: 1) the area below the demand curve between Q'_0 and Q_E; 2) the area above

the negative portion of the MC curve between Q'_0 and Q_B; and 3) the area below the positive portion of the MC curve between Q_E and Q_B.

As can be seen from Figure 3, an increase in demand beyond D_1 leads to a fall in output Q in the absence of the optimum toll. However, in the presence of the toll, an increase in demand unambiguously leads to an increase in output.

Figure 3 shows that imposing the optimum toll results in a lower AC when equilibrium is on the backward-bending portion of the AC curve (compare points H and B). However, if demand is given by D_1, then the optimum toll actually lowers AC inclusive of the toll (compare points E and B). In other words, the reduction in congestion costs more than compensates for the optimum toll. Thus, the congestion toll leads to an increase in the welfare of road users (over and above the revenues accruing to the agency administering the toll), and they should be in favor of the toll in such a case.

IV. Concluding Comments

In this paper, we have shown that in the case of a common property resource characterized by congestion, the optimum tax may lead to an increase in output. Moreover, an increase in demand may lead to a fall in output in the absence of the optimum tax but not in the presence of the tax. This applies to road travel, shopping, monopoly power in international trade (immiserizing growth), and other, and may apply to any industry characterized by negative economies external to the firms but internal to the industry.

In the case of road travel, we clarified the relationship between travel cost, the number of cars on the road at a moment in time (inputs), and the number of trips or volume of cars per unit of time (output). We showed that imposing the optimum toll may lead to an increase in the number of trips per unit of time, to a reduction in the toll-inclusive travel cost, and to an increase in the road users' welfare. In those cases, imposing the optimum toll reduces the amount of congestion not only because of a fall in demand but also because of an increase in the number of trips "supplied" by the road.

Notes:

1 In the case of forests, some externalities may still exist. For instance, a fire in one part of the forest can spread to adjacent part.

2 The increase in average travel cost between points A and B is $W/S_1 - W/S_2$ (see equation 4).

3 In steady-state, density (number of cars per mile) is uniform at any point along the road. Hence, we can abstract from complications related with dynamic adjustments in density. In what follows, the analysis deals with comparative statics, and not with the transition from one equilibrium to another when density varies along the road.

4 Newbery also states that the upward-sloping part of S(Q) is dynamically unstable and will occur in cases such as bottlenecks (say because of a narrowing of a road). In fact the upward-sloping portion of S(Q) can represent a stable situation, such as might be caused by a permanent increase in transport demand on a given road system, or by an increase in demand at certain hours of the day (rush hour). In the latter case, the optimal toll will be time-dependent.

5 Walters (1968, p. 25) notes that the unit cost curve bends backwards if the density L increases beyond the point where $Q = Q_B$. However, he analyzes congestion issues only in the upward-sloping range of the AC curve. Shah also mentions the possibility of a backward-bending AC curve but, noting that the optimum is in the upward-sloping portion, does not consider the former in his empirical analysis of optimal taxation.

6 Point F in Figure 3 corresponds to points F and F' in Figure 1.

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MODELS OF WAGE DETERMINATION AND THE INDUSTRY WAGE STRUCTURE IN URUGUAY*

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Abstract:

This paper examines the wage structure in Uruguayan manufacturing during the period 1968 to 1987. It analyzes the size and stability of intre-industry wage differentials, and compares these differentials across occupations, establishment sizes, and across countries. The paper also relates industry wage levels to industry characteristics. The analyses are used to test the competitive and the efficiency models of wage determination.
The results confirm the predictions of the efficiency wage model, as wage differentials are substantial, they persist over time, they are strongly correlated between white– and blue-collar workers, and to a lesser extent, across establishment sizes. In addition, some industry characteristics are positively correlated to wages.

I. Introduction

The study of inter-industry wage differentials has received an increased attention in the recent labor market literature. Several papers have been devoted to examine the pattern of wage differentials in the U.S. economy. They have consistently found a number of facts: the magnitude of the differentials is considerable; they persist even after controlling for human capital variables; they have been remarkably stable over long periods of time; and they are similar across countries and occupations.

Competitive and non-competitive models of wage determination give alternative explanations for the existence of wage differentials. The competitive model explains wage

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