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CHARGES ON TRANSPORT – TO WHAT EXTENT ARE THEY PASSED ON TO USERS?

by

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Abstract

The paper first briefly reviews the extent to which profit maximising transport firms with identical cost functions and producing identical transport services pass on output charges to transport users under perfect competition, under different forms of imperfect competition and when they act as monopolists. Then the analysis is extended to derive the pass-on rates and traffic reductions of an output tax when firms care both about profit and consumer surplus, produce symmetrically differentiated services and compete simultaneously in quantities and fare and when they collude. The pass-on rates and traffic reductions are highest (lowest) under quantity competition and lowest (highest) under collusion given that the firms produce substitutable (complementary) services. The results are also discussed in the light of the firms’ objective functions and the degree of substitutability or complementarity between the services. Two important counterintuitive results are that the more intense the firms compete and the more weight they put on consumer surplus, the higher the pass-on rates are.

Keywords: Pass-on rates; Firms’ objectives, imperfect competition, collusion, oligopoly
1. Introduction

Taxes on transport can have two main purposes: to raise revenues for the government to undertake government functions and provide goods or services that the market by itself would not typically provide (such as defence) or to correct market failures. The first type of tax is ‘distortive’ and the second type of tax is ‘corrective’, also called ‘Pigouvian’, in honour of Arthur Pigou, who first suggested the use of these taxes to internalize externalities, see for example Button (2010). Both types of taxes change relative prices (either for consumers or producers or both) and influence behaviour by increasing the marginal cost of production or consumption activities.

The effects of a quantity (i.e., per unit) tax on transport users, transport operators and market size under perfect competition have been thoroughly discussed, and the model is readily available in ordinary microeconomics textbooks, such as Varian (2003), Nicholson (2005) and Frank (2006). The pass-on rate of taxes to demanders when firms are profit maximising monopolists are, however, more scarcely dealt with in the same textbooks, but several articles and reports deal with this issue (see for example Bulow and Pfleiderer, 1983; Kate and Niels, 2005 and Jørgensen et al., 2011). Kate and Niels (2005) also discuss the cost pass-on to consumers in some cases of imperfect competition whilst Jørgensen et al. (2011) focus on aviation charges in particular and to what extent an air transport company operating as a monopolist will pass them to consumers under different assumptions regarding its demand and cost functions.

None the above mentioned research nor, to our knowledge, other research, has dealt with the question of to what extent firms pass the tax along to consumers when the firms: (1) have other goals beyond traditional profit maximisation, and (2) compete in either quantities or prices and when the degree of competitiveness between them varies. These issues are particularly relevant as far as taxing of transport activity is concerned. Although there are good reasons to believe that many transport operators are not pure profit maximisers and there is a substantive literature on the impact of management objectives on transport pricing (Nash, 1978; Glaister and Lewis, 1978; Jørgensen and Pedersen, 2004; Jørgensen and Preston, 2007 and Clark et al., 2009) there has not been much research on the pass-on rate of taxes from producers to consumers in the transport sector. Also, how the effects of taxes vary with different forms of imperfect competition between transport operators and in particular how intense they compete, are somewhat neglected issues.
Given the above, the aim of this paper is to bring transport firms’ goals and the market structure in which they operate together in one model and then discuss the effects on transport users’ prices and demand of an equal per unit tax on all suppliers. In line with Jørgensen and Pedersen (2004), Jørgensen and Preston (2007) and Clark et al. (2009) we assume that transport firms maximise a weighted sum of profits and consumer surplus. There are two reasons for our choice of goal function for transport firms. First, public bodies and/or local interests in many countries hold a considerable amount of shares in transport firms serving both local markets (bus transport, fast craft services) and national/international markets (rail and air transport firms).\(^1\) Second, managers often have some power to pursue their own goals (Williamson, 1974). Thus, it is not unreasonable to assume that transport operators are not typically pure profit maximisers. Moreover, we assume one (monopoly or collusion case) or two suppliers who compete simultaneously in either quantities (Cournot) or prices (Bertrand).

The structure of the paper is as follows. In section 2 we briefly review the determinants of the degree of pass-on rates to transport users when suppliers are profit maximisers operating under different competitive situations. In section 3 we present duopoly models when firms have mixed goals. Using the results from section 3, in section 4 we discuss the impacts of a per unit tax on prices and level of quantity transported. We do so paying particular attention to how the weight transport firms place on profit versus consumer surplus, and how the industry structure in which they operate (collusion, Bertrand competition, or Cournot competition) together with the intensity with which they compete influence the impact of the tax on prices and demand. Lastly, in section 5 we summarise the most important results and their policy implications.

\(^1\) In Norway, for example, public bodies in 2004 held the majority of shares in 36 of the 95 bus companies (Mathisen and Solvoll, 2008). The states of Norway, Sweden and Denmark held 14 %, 21 % and 14 % of the shares in the dominant air company (SASBraathen) in Scandinavia and the French government is a shareholder, albeit with less than 20% of the shares, of Air France-KLM. There is also some degree of public ownership of other air and rail companies in many European countries, see Blauwens et al. (2008); Clark et al. (2009) and Button (2010). In the US, the Washington Metropolitan Area Transit Authority, a government agency, operates all public transport in the Washington DC metropolitan area, including rail and underground, buses, and vans for the disabled.
2. The pass-on rate for profit maximising transport firms – a brief review

2.1 Definition of tax pass-on rate

The per unit tax pass-on rate can be defined as the ratio between the change in price and the change in tax. In other words, it measures the impact that an infinitesimal change of a per unit tax \( t \) on the final output (passenger, tonne etc) has on the equilibrium price, \( P^* \), and can be described by \( \frac{\partial P^*}{\partial t} \). Examples in transport economics include air transport fare increases when airlines face higher landing fees or new taxes or charges per passenger, higher costs of transporting goods by sea when shipping companies have to pay higher harbour charges per tonne loaded or reloaded, to name just a couple. The lower (higher) the value of \( \frac{\partial P^*}{\partial t} \), the less (more) of the tax increase is paid by consumers and the more (less) is paid by the producer. When \( \frac{\partial P^*}{\partial t} \geq (\leq) 1 \) the final price (tax inclusive) to users goes up by more than, the same as or less than the amount of the tax.

In this section we briefly review the pass-on rates under the most common types of market competition between transport firms

2.2 Free competition

This market structure applies in particular to road freight and sea freight in most European countries and it has also become more common in some passenger transport industries over the last thirty years\(^2\), although perhaps not as much as it would have been expected (see Blauwens et al., 2008).

Suppose \( P \) is price, \( X \) the number of units (tonnes, passengers, etc) transported, \( t \) the tax per unit transported and \( X = S(P) \) and \( X = D(P) \) denote the supply function and demand functions, respectively. The effect on the equilibrium price, \( P^* \), of the tax is then given by, see for example Nicholson (2005):

\[
\frac{dP^*}{dt} = \frac{E_S}{E_S - E_D}
\]

where

\[
E_S = \frac{dS(P)}{dP} \frac{P}{X}, \quad E_D = \frac{dD(P)}{dP} \frac{P}{X}
\]

(1)

\(^2\) In air transport, this trend started with the Air Deregulation Act of 1978 in the US. In Europe, three airline liberalisation packages were introduced progressively between 1988 and 1997 (Graham and Guyer, 2009). The third package gradually introduced freedom to provide services within the European Union, including cabotage, so that an airline of one Member State was allowed to offer a route within another Member State (IATA website). Open Skies are also very common. These are bilateral and multilateral air transport agreements, aimed at increasing competition. The US and the EU signed an important such agreement in 2007, which became operational in 2008.
and denote elasticities of supply and demand with respect to fare, respectively. Since $E_S > 0$ and $E_D < 0$ it follows from (1) that imposing a tax per unit will increase the equilibrium price ($P^*$). This increase depends on the shapes of the demand and supply curves; it is easily seen from (1) that consumers bear a higher burden of the tax the more elastic the supply ($E_S$) and the more inelastic the demand ($E_D$ in absolute value) and vice versa. If, for example, $E_D = -0.8$ and $E_S = 0.6$, $\frac{dP^*}{dt} = 0.43$. Transport users in this case pay 43% and suppliers pay 57% of the tax increase.

### 2.3 One supplier (monopoly)

The deregulation trend observed in many transport markets in a number of countries since the late 1970s has, as emphasised above, increased competition to some extent. Yet, some transport suppliers can still act as monopolists, at least when it comes to passenger transport between certain destinations (Blauwens et al., 2008). Dobruszkes (2009) finds that although the liberalisation of the intra-European air market has increased competition very few routes are actually served by a significant number of competitors. Barcelona-Belfast is, for example, only served by one airline. The same is the case between a number of destinations in Norway. In the United States the only train company for interurban passenger travel is Amtrak, a clear monopoly.

Differentiating the first order conditions for profit maximisation with respect to tax ($t$) we get, after some mathematical manipulation (see Bulow and Pfleiderer, 1983 and Kate and Niels, 2005):

\[
\frac{dP^*}{dt} = \frac{X_P(P)}{2X_P(P)+X_{PP}(P)(P^*-C_X(X)-t)-C_{XX}(X)X_P^2(P)} > 0 \tag{2}
\]

where $P^*$, $X(P)$ and $C(X)$ denote the monopolist’s optimum price, demand function and cost function, respectively.

Equation (2) yields several interesting conclusions. First, when the demand and cost functions are linear ($X_{PP} = C_{XX} = 0$) it follows that $\frac{dP^*}{dt} = 1/2$, meaning that the transport firm will always pass half of the tax along to transport users, no matter how steep these functions are. Second, when the cost function is convex ($C_{XX} > 0$) and the demand function, linear,

\[^3\text{Here and throughout the paper } X_P = \frac{dX}{dP}, X_{PP} = \frac{d^2X}{dP^2} \text{ etc.}\]
\[ \frac{dP^*}{dt} < \frac{1}{2}, \]  and the transport firm will always pass on less than half of the tax amount to users. Third, under the assumption that the monopolist must have non-negative profits 
\((P^* - C_X - \ell) > 0\), the cost function is linear and the demand function is convex \((X_{PP} > 0)\), 
\[ \frac{dP^*}{dt} > \frac{1}{2}, \text{ and the firm will always pass on more than half of the tax to users.} \]
Fourth, when both the demand and cost functions are convex, 
\[ \frac{dP^*}{dt} \geq (\text{<})1/2; \text{ and so the firm may pass on more than, just, or less than half of the tax.} \]

2.4 Oligopoly

Oligopoly is a market structure in which there are a small number of producers. Because the number is small, the actions of one firm influence and are influenced by the rivals’ actions. This market situation is commonplace for many passenger transport markets. In Norway, for example, one or two suppliers on many routes are commonplace in air transport, just as they are in the rest of Europe, despite the opening of the air transport market to competition, a point we already highlighted in the previous section. Hamburg-Budapest, Hamburg-Berlin and Hamburg–Düsseldorf are examples of routes served by just two airlines (Dobruszkes, 2009, Table 1, p.31). In the UK most train routes are served by one or two companies. These are franchises from the government to private operators to serve specific routes.

In order to obtain fairly simple and unambiguous results on tax pass-on rates for different kinds of competition, we assume that all \(N\) firms have equal linear demand and cost functions; that is they have the same cost structure and produce homogenous services. Taking the results in Kate and Niels (2005) and Clark et al. (2010) as starting points, we can derive the following conclusions regarding the effects on equilibrium price \((P^*)\) of imposing a per unit tax \((t)\) on all \(N\) suppliers:

- Under simultaneous quantity competition (Cournot), 
  \[ \frac{dP^{*C}}{dt} = \frac{N}{N+1}, \text{ where } P^{*C} \text{ is the Cournot equilibrium price. The value of } \frac{dP^{*C}}{dt} \text{ increases with } N \text{ but is always below } 1. \]

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4 In Jørgensen et al. (2011) it is shown that for the specific demand functions \(X(P) = aX^{-b}\) where \(a > 0, b > 1\) and \(X(P) = ce^{-dx}\) where \(c,d > 0\), it follows that 
\[ \frac{dP^*}{dt} = \frac{b}{b-1} \text{ and } \frac{dP^*}{dt} = 1, \text{ respectively, given a linear cost function.} \]
5 Some standard-class train fares are regulated by the government in the UK. These are typically commuter tickets for travel at peak times.
6 Kate and Niels (2005) show some rules of thumb for pass-on rates under Cournot competition when the demand and cost functions are non-linear. We will, however, not go further on these issues here.
This means that the pass-on rate to transport users increases as the number of competitors increase; when for example \( N = 2 \) and \( N = 3 \), \( \frac{dP^C}{dt} \) is 2/3 and 3/4, respectively.

- Under sequential quantity competition (Stackelberg), \( \frac{dP^{CL}}{dt} = \frac{1}{2} \) for the leader and \( \frac{dP^{CF}}{dt} = \frac{2N-1}{2N} \) for the \((N-1)\) followers where \( P^{CL} \) and \( P^{CF} \) are the equilibrium prices for the leader and followers, respectively. The leading firm will always pass half of the tax along to users whilst the pass-on rate from the followers is between \( \frac{1}{2} \) and 1 and will approach 1 as the number of followers increase. For example, when \( N = 2 \) and \( N = 3 \), \( \frac{dP^{CF}}{dt} \) is 3/4 and 5/6, respectively.

- Under simultaneous fare competition (Bertrand), \( \frac{dP^B}{dt} = 1 \), where \( P^B \) is the equilibrium price. The transport operators will, thus, pass on exactly the amount of the tax to users.

- Also under sequential fare competition the transport firms will pass all the tax along to users; that is \( \frac{dP^{BL}}{dt} = \frac{dP^{BF}}{dt} = 1 \) where \( P^{BL} \) and \( P^{BF} \) are equilibrium prices for the leader and followers, respectively.

### 2.5 Summary of results for profit maximising firms

The pass-on rate to transport users from profit maximising firms operating under perfect competition depends on the shapes of the demand and supply curves; the more inelastic the demand and the more elastic the supply, the more are users penalised by the tax.

The pass-on rate to users from firms operating as monopolists critically depends on the forms of the demand and cost functions; it can vary from nearly zero (convex cost functions) to more than one (convex demand functions). When both functions are linear the monopolist will pass on exactly half of the tax to consumers, regardless of the steepness of the functions.

Under Cournot competition with linear demand and cost functions and homogenous transport services, the firms will, however, pass more than half of the tax along to users. The same is the case for the followers under Stackelberg competition whilst the leader, like the monopolist, will always pass on half of the tax. All suppliers, except the leader will pass on more of the tax to the consumers when the number of suppliers increases. This result is probably in conflict with what many think.
Under all types of price competition the firms will pass on the whole tax to transport users for all common forms of demand and cost functions.

3. Equilibrium prices and quantities when transport firms have mixed goals and produce different services

All the results in section 2 assume profit maximising firms producing homogeneous transport services. In this section we relax both assumptions. Transport operators have mixed goals and produce symmetrically differentiated services. We focus on the cases where two firms compete simultaneously in quantity (Cournot), in fares (Bertrand) and when they collude. In this section we present the model that makes the basis for our discussion in section 4 about pass-on rates and traffic effects of a per unit tax. In order to focus on tax effects in particular, the model builds up on the model developed by Clark et al. (2009) by introducing a per unit tax (t) in the firms’ cost function. For a thorough discussion of the model and its choice of users’ utility function and of goal function for the transport operators and other functional assumptions, we refer to Singh and Vives (1984), Lewis and Sappington (1988), Jørgensen and Preston (2007) and Clark et al. (2009).

3.1 The model

In line with Sing and Vives (1984) we assume that a representative transport user’s utility \(U\) depends on the level of use of the services supplied by transport firm 1, \(X_1\) and firm 2, \(X_2\), in the following way:

\[
U(X_1, X_2) = X_1 + X_2 - \left( \frac{X_1^2 + 2sX_1X_2 + X_2^2}{2} \right)
\]

where \(s \in [-1,1]\) measures the degree of substitutability between the services offered by the firms; when \(s = -1\) the services are perfect complements, when \(s = 0\) they are independent and when \(s = 1\) they are perfect substitutes. Hence, when \(s < 0\) and increases, the degree of complementarity between the services decreases, when \(s > 0\) and increases the services become closer substitutes.
When ignoring the income effect, the transport user maximises his consumer surplus, which can be described by 
\[ CS = U(X_1, X_2) - \sum_{i=1}^{2} P_i X_i, \]
where \( P_i \) is the price paid for the services provided by firm \( i \) and \( i=1,2 \).

The consumer surplus’ maximisation yields the following direct demand functions for the two services:
\[
X_1 = \frac{1}{1 + s} - \frac{P_1}{1 - s^2} + \frac{sP_2}{1 - s^2}, \quad X_2 = \frac{1}{1 + s} - \frac{P_2}{1 - s^2} + \frac{sP_1}{1 - s^2} \tag{4}
\]

Inverting the demand system in (4) yields the following inverse demand functions
\[
P_1 = 1 - X_1 - sX_2, \quad P_2 = 1 - X_2 - sX_1 \tag{5}
\]

The transport firms, thus, produce symmetrically differentiated services. Equations (4) and (5) show that using our chosen utility function leads to simple and easily tractable demand functions. Other special cases of the commonly used CES utility function (constant elasticity of substitution) such as the Cobb-Douglas function give either unrealistic demand functions (Cobb-Douglas implies constant shares of income devoted to each service) or to complicated (non-linear) demand functions (see for example Nicholson, 2005).

Assume, for example, demands of \( X_1^* \) and \( X_2^* \) for firms 1 and 2, respectively. Plugging equations (3) and (5) into 
\[ CS = U(X_1, X_2) - \sum_{i=1}^{2} P_i X_i \]
gives the following expression for total consumer surplus, \( CS^* \):

---

7 Income effect in transport is often ignored because (a) the proportion of total expenditure allocated to travel is typically not significant, and (b) including the income effect ‘adds complexity to both the estimation of the demand models and the assessment of the benefits’ (Cherchi and Polak, 2007).

8 The firms produce symmetrically differentiated services since \( \frac{\partial X_1}{\partial P_2} \frac{\partial X_2}{\partial P_1} = \frac{s}{1-s^2} \). An \( s \)-value of for example 0.4 (-0.4) implies that \( \frac{\partial X_1}{\partial P_2} \frac{\partial X_2}{\partial P_1} = 0.48 \) (-0.48) and \( \frac{\partial X_1}{\partial P_1} \frac{\partial X_2}{\partial P_2} = -1.19 \) (-1.19).
Assume that the firms have the following identical cost functions, $C_i, (i = 1, 2)$, and pay the same tax ($t$) per unit of output:

$$C_1(X_1) = cX_1 + tX_1 = (c + t)X_1, \quad C_2(X_2) = cX_2 + tX_2 = (c + t)X_2, \quad 0 < (c + t) < 1 \quad (7)$$

Equations (5) and (7) can be plugged into the standard profit expression to yield the following expressions for the firms’ profits, $\pi_i, (i = 1, 2)$:

$$\pi_1 = (1 - X_1 - sX_2 - c - t)X_1, \quad \pi_2 = (1 - X_2 - sX_1 - c - t)X_2 \quad (8)$$

Instead of the firms being pure profit maximisers, they now maximise a weighted sum ($WS_i, i = 1, 2$) of their profits and transport users’ total consumer surplus ($CS$):

$$WS_i = (1 - \beta)\pi_i + \beta CS \quad i = 1, 2, \quad \beta \leq 1/2 \quad (9)$$

In (9) we assume that both firms have the same objective function (same value of $\beta$) and that both are concerned about users’ consumer surplus ($CS$), including those users that choose the rival firm’s services. This is a reasonable assumption when both transport operators serve the same population. When $\beta = 0$ the firms are pure profit maximisers, when $\beta = 1/2$ they place equal weight on profits and consumer surplus. If we assume a tax deadweight loss of zero and marginal social costs of service provision are $(c + t)$, then the transport operators maximise social surplus when they put equal weight on profits and consumer surplus ($\beta = 1/2$) and compete in prices or collude.\(^9\) In intermediate cases the firms put a higher weight on profits than on consumer surplus. Of course, our choice of objective function is open to debate. However, assuming that producers have other objectives on top of profit maximisation is, as we emphasised in section 1, in many cases more realistic. For a thorough discussion of the goal function above as far as transport suppliers are concerned, we refer to Jørgensen and Preston (2007) and Clark et al. (2009).

\(^9\) It follows from equations (10) and (14) that equilibrium prices under collusion and Bertrand are equal to $(c + t)$ when $\beta = 0.5$. When the firms compete in quantities (Cournot), equation (12) shows, however, that the equilibrium price differs from $(c + t)$ when $\beta = 0.5$ and $s \neq 0$. 
3.2 Market solutions for different kinds of competitive situations

Simultaneous fare competition (Bertrand)

Under Bertrand competition the firms maximise their objective functions $WS_i(i = 1,2)$ by setting prices strategically. Plugging equations (9), (11), (12) and (13) in (14) gives the following common equilibrium price $P^{*B}$ and common equilibrium quantity $X^{*B}$ for each firm:

\[ P^{*B} = \frac{(1 - \beta)(c + t) + (1 - 2\beta)(1 - s)}{s(2\beta - 1) - (3\beta - 2)} \]  \hspace{1cm} (10)

and

\[ X^{*B} = \frac{(1 - \beta)(1 - c - t)}{s(2\beta - 1) - (3\beta - 2)(1 + s)} \]  \hspace{1cm} (11)

Simultaneous quantity competition (Cournot)

Under Cournot competition the transport operators maximise their objective functions by choosing the quantities they will supply. Using equations (10) to (14) gives the following common equilibrium price $P^{*C}$ and common equilibrium quantity $X^{*C}$ for each firm:

\[ P^{*C} = \frac{(1 - \beta)(1 + s)(c + t) - \beta(2 + s) + 1}{s(2\beta - 1) - (3\beta - 2)} \]  \hspace{1cm} (12)

and

\[ X^{*C} = \frac{(1 - \beta)(1 - c - t)}{s(2\beta - 1) - (3\beta - 2)} \]  \hspace{1cm} (13)
Collusion

When the firms collude they maximise $WS = WS_1 + WS_2$ and we get the following equilibrium price $P^{*\text{COLL}}$ and quantity $X^{*\text{COLL}}$ for each firm when using equations (10) to (14):\(^{10}\)

\[
P^{*\text{COLL}} = \frac{(1 - \beta)(c + t) + 1 - 2\beta}{2 - 3\beta} \tag{14}
\]

and

\[
X^{*\text{COLL}} = \frac{(1 - \beta)(1 - c - t)}{(2 - 3\beta)(1 + s)} \tag{15}
\]

Stability and existence conditions

The restrictions previously imposed on the values of $s$, $\beta$ and $(c+t)$ secure that all numerators and denominators are positive in the expressions for equilibrium prices and quantities above, implying that $P^{*j}, X^{*j} > 0$, $(j = B, C, \text{COLL})$. These results will be used later on. Clark et al. (2009) also show that the bindings on $s$, $\beta$ and $(c+t)$ are sufficient to conclude that interior equilibria exist for all competitive situations described above. \(^{11}\)

Given the conditions above, it is straightforward to verify from equations (10) – (15) that all equilibrium prices (quantities) are increasing (decreasing) in costs and decreasing (increasing) the greater emphasis the firms place on consumer surplus and the more intensely they compete; that is $\partial P^{*j}/\partial c > 0$, $\partial P^{*j}/\partial \beta$, $\partial P^{*j}/\partial s < 0$ and $\partial X^{*j}/\partial c < 0$, $\partial X^{*j}/\partial \beta$, $\partial X^{*j}/\partial s > 0$ $(j = B, C, \text{COLL})$.

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\(^{10}\) In this case the solutions are the same regardless of whether the firms use fare or quantity as their decision variable.

\(^{11}\) For a thorough discussion of stability conditions in oligopoly in general, see Sead (1980).
4 Tax influence under mixed goals and for different competitive situations

4.1 The pass-on rates

Using equations (10), (12) and (14) we can now derive the pass-on rates, represented by the derivatives of the equilibrium prices with respect to tax for the Bertrand case, the Cournot case and the collusion case, respectively. Thus:

\[
\frac{\partial P^B}{\partial t} = \frac{(1 - \beta)}{s(2\beta - 1) - (3\beta - 2)}
\]

and

\[
\frac{\partial P^C}{\partial t} = \frac{(1 - \beta)(1 + s)}{s(2\beta - 1) - (3\beta - 2)}
\]

and

\[
\frac{\partial P^{COLL}}{\partial t} = \frac{(1 - \beta)}{2 - 3\beta}
\]

Under the restrictions placed on the values of \( \beta, s \) and \( (c + t) \) it is easy to verify that all three derivatives above are positive, which means that the transport firms pass on at least part of the tax to consumers, regardless of the weight the firms put on profits versus consumer surplus (value of \( \beta \)) and their competitive situation. It can also be deduced from the formulae above that \( \frac{\partial P^B}{\partial t}, \frac{\partial P^{COLL}}{\partial t} \leq 1 \) when \( \leq 0.5 \), which means that under price competition and collusion the prices to consumers will never go up by more than the amount of the tax. Under quantity competition, however, it follows from equation (17) that

\[
\frac{\partial P^C}{\partial t} \leq (>) 1 \text{ when } s \leq (>) \frac{1-2\beta}{2-3\beta}.
\]

This condition implies that operators will pass on less than the tax amount to consumers when they produce complementary services; that is \( \frac{\partial P^C}{\partial t} < 1 \) when \( s < 0 \). When the firms compete fiercely, implying \( s > 0.5 \), the pass-on rate is always
higher than one. In intermediate cases when the firms compete to a moderate degree
\((0 < s < 0.5)\) the result is ambiguous, as the final price to users may go up by more than,
just as or less than the amount of the tax. The higher the weight the firms put on consumer
surplus (higher \(\beta\)) the more likely it is that the pass-on rate will be higher than one.

A closer look at the derivatives above enables us to derive the following rankings of the
pass-on rates:

\[
\frac{\partial P^*}{\partial s} > \frac{\partial P^*}{\partial t} > \frac{\partial P^{\text{COLL}}}{\partial t} \quad \text{when } s > 0 \text{ and } \beta < 0.5,
\]

\[
\frac{\partial P^*}{\partial s} > \frac{\partial P^*}{\partial t} = \frac{\partial P^{\text{COLL}}}{\partial t} = 1 \quad \text{when } s > 0 \text{ and } \beta = 0.5
\]

\[
\frac{\partial P^*}{\partial s} = \frac{\partial P^{\text{COLL}}}{\partial t} = \frac{\partial P^*}{\partial t} \quad \text{when } s = 0
\]

\[
\frac{\partial P^*}{\partial s} < \frac{\partial P^*}{\partial t} < \frac{\partial P^{\text{COLL}}}{\partial t} \quad \text{when } s < 0 \text{ and } \beta < 0.5
\]

\[
\frac{\partial P^*}{\partial s} < \frac{\partial P^*}{\partial t} = \frac{\partial P^{\text{COLL}}}{\partial t} = 1 \quad \text{when } s < 0 \text{ and } \beta = 0.5
\]

When the transport operators produce substitute services \((s > 0)\) Cournot competition yields
the highest pass-on rates. At the other end of the spectrum, users are the least penalised by the
tax when the operators collude, given that they give a higher weight to profits than to
consumer surplus \((\beta < 0.5)\). When the firms weigh profit and consumer surplus equally
\((\beta = 0.5)\) the pass-on rate is still highest under Cournot competition but equal to 1 both when
the firms collude and compete in fares. Some of the conclusions above are reversed when the
firms produce complementary services \((s < 0)\). When \(\beta < 0.5\) the pass-on rate is then highest
when the firms collude and lowest when they compete in quantities. The pass-on rates are,
however, still equal to 1 when the firms collude or compete in fares and give the same weight
to profit and consumer surplus \((\beta = 0.5)\).
Moreover, after some mathematical manipulation we get the following cross derivative expressions using equations (16), (17) and (18):

\[
\frac{\partial^2 p^B}{\partial t \partial \beta} = \frac{1 - s}{[s(2\beta - 1) - (3\beta - 2)]^2} > 0 \text{ when } s < 1 \tag{19}
\]

\[
\frac{\partial^2 p^B}{\partial t \partial s} = \frac{1 + \beta(2\beta - 3)}{[s(2\beta - 1) - (3\beta - 2)]^2} > 0 \text{ when } \beta < 0.5 \tag{20}
\]

\[
\frac{\partial^2 p^c}{\partial t \partial \beta} = \frac{1 - s^2}{[s(2\beta - 1) - (3\beta - 2)]^2} > 0 \text{ when } s < 1 \tag{21}
\]

\[
\frac{\partial^2 p^c}{\partial t \partial s} = \frac{(1 - \beta)(3 - 5\beta)}{[s(2\beta - 1) - (3\beta - 2)]} > 0 \tag{22}
\]

\[
\frac{\partial^2 p^{col}}{\partial t \partial \beta} = \frac{1}{[2 - 3\beta]^2} > 0, \quad \frac{\partial^2 p^{col}}{\partial t \partial s} = 0 \tag{23}
\]

When the services are not perfect substitutes \((s < 1)\) it follows from equations (19), (21) and (23) that for all competitive situations firms will pass on more of the tax to transport users the higher the weight they place on consumer surplus relative to profit \((\text{higher } \beta)\). Also, given that the firms do not collude, the less complementary the services the firms produce are or the more intensely the firms compete \((\text{higher } s)\), the greater the share of the tax that will be paid by users, except for the case when the firms compete in fares \((\text{Bertrand})\) and weigh profit and consumer surplus equally \((\beta = 0.5)\). Finally, when the firms collude, the pass-on rate is, as expected, unaffected by the value of \(s\) or the demand relationship between their services.

\[\text{12 The nominator in (20), } (1 + \beta(2\beta - 3)), \text{ is zero when } \beta = 0.5.\]
Using equations (16), (17) and (18) the pass-on rates when the firms compete in fares, in quantities and when they collude are visualised in Figure 1, Figure 2 and Figure 3, respectively. In each figure the relationships between pass-on rates and how intensely they compete (value of $s$) are drawn when they maximise profits ($\beta = 0$), when they place 2.3 times higher weight on profits than consumer surplus ($\beta = 0.3$)\(^\text{13}\) and when they weigh profits and consumer surplus equally ($\beta = 0.5$).

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Figure 1. Tax pass-on rates from the firms when they compete in fares.

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Figure 2. Tax pass-on rates from the firms when they compete in quantities.

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\(^{13}\) When $\beta = 0.3$, $(1-\beta) = 0.7$ and the firms weigh profits 2.3 times higher than consumer surplus.
The figures above support previous conclusions; the higher the weight the firms put on consumer surplus relative to profits (higher $\beta$) the higher the pass-on rates are for all competitive situations. Moreover, comparing the lines in the figures above we can conclude that when the firms put less weight on consumer surplus than on profits ($\beta < 0.5$), and produce substitutable (complementary) services the pass-on rates are higher (lower) when they compete than when the collude. Additionally, it follows from Figure 1 and Figure 2 that the pass-on rates under Bertrand and Cournot competition increase convexly with $s$ when $\beta < 0.5$, and are most dependent on $s$ under quantity competition. When $\beta = 0.5$, however, the figures show that the pass-on rates are unaffected by $s$ when the firms compete in prices and increase linearly with $s$ when the firms compete in quantities. Under collusion the pass-on rates are always unaffected by $s$.

4.2 The influence of the tax on quantity transported

As emphasised earlier, one important reason to impose taxes on transport operators is to influence the level of activity, for example, if this is deemed to be excessive (i.e., inefficient
from an economic point of view). Let us, therefore, have a closer look on how a per unit tax on output influences the total number of units transported in our model setting. Using equations (11), (13) and (15) and bearing in mind that total number of units transported under Bertrand, Cournot and Collusion is \( 2X^B \), \( 2X^C \) and \( 2X^{COLL} \), respectively, we get the following derivatives:

\[
\frac{\partial 2X^B}{\partial t} = \frac{2(\beta - 1)}{(s(2\beta - 1) - (3\beta - 2))(1 + s)} \quad (24)
\]

and

\[
\frac{\partial 2X^C}{\partial t} = \frac{2(\beta - 1)}{s(2\beta - 1) - (3\beta - 2)} \quad (25)
\]

and

\[
\frac{\partial 2X^{COLL}}{\partial t} = \frac{2(\beta - 1)}{(2 - 3\beta)(1 + s)} \quad (26)
\]

All derivates above are negative, which means that imposing a higher tax per unit on the firms leads to lower quantities transported, regardless of how the firms weigh profit relative to consumer surplus and their competitive environment. A further inspection of the derivates above makes it possible to verify the following ranking:

\[
\frac{\partial 2X^C}{\partial t} < \frac{\partial 2X^B}{\partial t} < \frac{\partial 2X^{COLL}}{\partial t} \quad \text{when } s > 0 \text{ and } \beta < 0.5,
\]

\[
\frac{\partial 2X^C}{\partial t} < \frac{\partial 2X^B}{\partial t} = \frac{\partial 2X^{COLL}}{\partial t} \quad \text{when } s > 0 \text{ and } \beta = 0.5
\]

\[
\frac{\partial 2X^B}{\partial t} = \frac{\partial 2X^{COLL}}{\partial t} = \frac{\partial 2X^C}{\partial t} \quad \text{when } s = 0
\]

\(^{14}\) This type of corrective tax may also be levied on transport users, and ideally should be equal to the marginal externality. However, per unit taxes on producers are sometimes more practical or politically acceptable, even though they are not first best corrective taxes. Another reason for governments to introduce new taxes is simply to raise revenues, even if these taxes distort relative prices and economic agents’ decisions.
\[ \frac{\partial^2 X^*}{\partial t \partial \beta} > \frac{\partial^2 X^B}{\partial t} > \frac{\partial^2 X^{C,L}}{\partial t} \text{ when } s < 0 \text{ and } \beta < 0.5 \]

\[ \frac{\partial^2 X^*}{\partial t \partial \beta} > \frac{\partial^2 X^B}{\partial t} = \frac{\partial^2 X^{C,L}}{\partial t} \text{ when } s < 0 \text{ and } \beta = 0.5 \]

When all derivatives above are negative we can conclude that for firms placing a higher weight on profits than on consumer surplus (\( \beta < 0.5 \)) a per unit tax has highest (lowest) negative impact on the total number of units transported when they compete in quantities (collude) and produce substitutable services (\( s > 0 \)). When they weigh profit and consumer surplus equally (\( \beta = 0.5 \)) the tax still has the highest negative impact on the total number of units transported under Cournot competition but its influence on the total number of units transported is the same regardless of whether the firms compete in prices or collude. When the firms produce complementary services (\( s < 0 \)) and \( \beta < 0.5 \) the conclusions above are reversed, so that the tax influence on the total number of units transported is highest when the firms collude or compete in prices and lowest when they compete in quantities. Just like the impact of the tax on equilibrium prices is the same regardless of whether the firms collude or compete in fares or quantities, the impact of the tax on the total number of units transported is also the same regardless of whether firms collude or compete in fares or quantities if they produce independent services (\( s = 0 \)).

Finally, from equations (24), (25) and (26), it follows that

\[ \frac{\partial^2 X^*}{\partial t \partial \beta} = \frac{-2}{1 + s} \cdot \frac{1 - s}{[s(2\beta - 1) - (3\beta - 2)]^2} < 0 \text{ when } s < 1 \quad (27) \]

\[ \frac{\partial^2 X^B}{\partial t \partial s} = \frac{2(1 - \beta)((1 - \beta) + 2s(2\beta - 1))}{[s(2\beta - 1) - (3\beta - 2)(1 + s)]^2} \geq (>) \text{ when } s \leq (>), \quad \frac{1 - \beta}{2(1 - 2\beta)} \quad (28) \]

\[ \frac{\partial^2 X^*}{\partial t \partial \beta} = \frac{2(s - 1)}{[s(2\beta - 1) - (3\beta - 2)]^2} < 0 \quad (29) \]
\[
\frac{\partial^2 2X^{*C}}{\partial t \partial s} = \frac{2\beta(3 - 2\beta) - 2}{[s(2\beta - 1) - (3\beta - 2)]^2} < 0 \text{ when } \beta < 0.5 \text{ (}= 0.5) \quad (30)
\]

\[
\frac{\partial^2 2X^{*\text{COLL}}}{\partial t \partial \beta} = \frac{-2}{(1 + s)[2 - 3\beta]^2} < 0, \quad \frac{\partial^2 2X^{*\text{COLL}}}{\partial t \partial s} = \frac{4 - 6\beta(2 - \beta)}{[(2 - 3\beta)(1 + s)]^2} > 0 \quad (31)
\]

Given that the firms do not produce identical services \((s < 1)\) the total number of units transported will be more negatively affected by the tax the higher the weight the firms put on consumer surplus relative to profits (higher \(\beta\)) for all competitive situations analysed here, as shown by equations (27), (29) and (31). Moreover, when the firms collude, increasing \(s\) leads to a lower negative impact of the tax on the total number of units transported for all actual values of \(\beta\). When the firms, however, compete in quantities and weigh profits more than consumer surplus \((\beta < 0.5)\), increasing \(s\) leads to the tax having a higher negative impact on the total number of units transported. When the firms weigh profit and consumer surplus equally, the reduction in the total number of units transported of a tax increase is unaffected by the value of \(s\).\(^{15}\) Finally, it follows from equation (28) that when the firms compete in prices a per unit tax will have lower (higher) negative influence on traffic when \(s\) increases, given that \(s < \langle > \frac{1 - \beta}{2(1 - 2\beta)}\). Since \(0 \leq \beta \leq 0.5\), \(s < \frac{1 - \beta}{2(1 - 2\beta)}\) when \(s < 0.5\). When the firms produce complementary services \((s < 0)\) or not compete very fiercely, a higher \(s\) leads to a lower impact of a per unit tax on the total number of units transported. When \(s > 0.5\) the opposite may occur; the higher the weight the firms put on profits relative to consumer surplus (lower \(\beta\)) the more likely it is that the impact of the tax on the total number of units transported will be higher when \(s\) increases.

\(^{15}\) The nominator in (30) is \((2\beta(3 - 2\beta) - 2)\). This is zero when \(\beta = 0.5\).
5. CONCLUDING REMARKS

The paper first briefly reviews the tax pass-on rates for profit maximising transport firms producing identical services under different types of competition. The pass-on rates under free competition (monopoly) are critically dependent on the shapes of the supply (cost) and demand functions. Under Bertrand competition the firms pass the entire tax on to users whilst the pass-on rates under quantity competition are lower than one. Under Cournot competition the pass-on rates increase with the number of competitors. Under sequential quantity competition, however, the leader will always pass on half of the tax to users whilst the pass-on rate from the followers is between $\frac{1}{2}$ and 1 and increases as the number of followers increases. It is worth noting that even profit maximising monopolists do not necessarily pass on all tax to users and given linear costs and demand functions they always pass less of the tax along than firms under all types of imperfect competition do.

Then the paper proceeds to analyse to what extent transport firms pass a per unit tax on output on to transport users and the subsequent impact the tax has on users’ demand: (1) when the firms compete simultaneously in prices (Bertrand), in quantities (Cournot) and when they collude; (2) when the degree of complementarity or substituability between the firms’ services differs; and (3) when the firms put different weights on profits and consumer surplus. The analysis is carried out assuming firms produce symmetrically differentiated transport services and have identical cost and goal functions. Their goal function is a weighted sum of profits and consumer surplus.

The paper shows, as expected, that all equilibrium prices (quantities) increase (decrease) when the government imposes a tax on outputs. This means that the transport firms in all cases pass at least part of the tax on to transport users. The pass-on rates differ, however,
significantly with the transport firms’ objective function and the market structure they operate in. When the firms produce substitutable services ($s > 0$) and place a higher weight on profits than on consumer surplus ($\beta < 0.5$) the pass-on rates are highest when the firms compete in quantities and lowest when they collude. These conclusions are reversed when they produce complementary services ($s < 0$). When the firms put equal weight on profits and consumer surplus ($\beta = 0.5$), the pass-on rates are the same and equal to 1 when they collude and compete in prices, regardless of whether the transport services are complements or substitutes. When they produce independent services ($s = 0$) the pass-on rates are the same for all three market structures described here.

When the services provided by the firms are not perfect substitutes ($s < 1$), the pass-on rates are higher the higher the weight the transport operators place on consumer surplus relative to profits ($\beta$ increases), regardless of whether they compete in prices, in quantities or collude. Since equilibrium prices always decrease when $\beta$ increases, the above means that imposing higher taxes on outputs makes equilibrium prices less dependent on the firms’ objectives. Moreover, increasing $s$ always leads to higher pass-on rates under Cournot competition. The same applies when the firms compete in fares and weigh profits more than consumer surplus ($\beta < 0.5$), but the pass on rate is less influenced by $s$ in this case than under Cournot competition. When the firms weigh profits and consumer surplus equally ($\beta = 0.5$) the pass-on rate under Bertrand competition is independent of $s$. Under collusion, the pass-on rates are independent of the degree of complementarity or substitutability between the services.

The tax impact on the total number of units transported is closely linked to its impact on the price faced by transport users (which in turn is linked to the pass-on rates). Higher (lower)
pass-on rates yield higher (lower) reductions in the total number of units transported. Moreover, when the services not are perfect substitutes, taxing transport firms’ outputs always leads to higher reductions in the total number of units transported, the higher the weight the firms put on consumer surplus relative to profits (higher $\beta$).

When the transport firms compete in quantities increasing $s$ leads to higher reductions in the total number of units transported as a result of the tax, given that they place more weight on profits than on consumer surplus ($\beta < 0.5$). When they value profits and consumer surplus equally ($\beta = 0.5$) the impact of the tax on the total number of units transported is, however, unaffected by the value of $s$. When the firms collude increasing $s$ leads to lower reductions in the total number of units transported as a result of the tax for all values of $\beta$. Under Bertrand competition the conclusions are not so clear-cut. When the firms are also concerned about consumers’ surplus ($\beta > 0$) and compete intensely such that $s > 0.5$ the total number of units transported can be more affected by the tax the more fiercely the firms compete (higher $s$ increases). When the firms run complementary services or substitute services to a limited degree ($s < 0.5$) increasing $s$ will moderate the impact of the tax on the total number of units transported; even though increasing $s$ results in higher pass-on rates.

Summing up, the most important message of the paper is that transport users are more penalised by an output tax imposed on transport firms the more concerned the firms are about users’ consumer surplus and the more intensely the firms compete. Policy makers tend to believe that profit maximising firms operating as monopolists or in areas with few suppliers pass on most of the tax to users. Our model suggests that this belief is wrong. Moreover, publically owned transport firms, which probably place a higher weight on
consumers’ surplus than private ones do, are typically perceived as unlikely to pass taxes on to users. Our model suggests that this belief is also wrong.

Future research could extend this model to assess the impact of different pass-on rates on social welfare under different market structures and producers’ goal functions.

References


