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Citation for final published version:

Jørgensen, Finn and Santos, Georgina 2014. Charges on transport – To what extent are they passed on to users? *Transportation Research Part A: Policy and Practice* 69 , pp. 183-195. 10.1016/j.tra.2014.08.006

Publishers page: <https://doi.org/10.1016/j.tra.2014.08.006>

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The definitive, peer-reviewed and edited version of this article is published and can be cited as

Jørgensen, F. and G. Santos (2014), 'Charges on Transport – To what extent are the passed on to users?', *Transportation Research Part A: Policy and Practice*, Vol. 69, pp. 183-95. DOI: 10.1016/j.tra.2014.08.006

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 taxes 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 activity reductions caused by 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 activity reductions are highest under collusion and lowest under Cournot competition when they produce complementary services. When they produce substitute services, the result is ambiguous and the competitive situation that yields highest pass-on depends on the firms' objective functions and how fiercely they compete. Two important counterintuitive results are that the more intensely the firms compete and the more weight they put on consumer surplus, the higher the pass-on rates are.

Keywords: Taxes, tax pass-through, pass-on rates, firms' objectives, imperfect competition, collusion

1. Introduction

Taxes on transport (and in general) can have three main purposes: (a) 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 the provision of roads), (b) to correct market failures (such as traffic congestion due to excessive demand for travel), and (c) to redistribute income or wealth from higher income groups to lower income groups. Examples of this last type include higher income earners paying higher tax rates on their income than lower income earners, and wealthier road users paying a congestion tax, which is then used to improve public transport for lower income groups. This congestion tax can be corrective,¹ raise revenues to fund public transport and redistribute wealth, all at the same time.

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; Ten Kate and Niels, 2005; Jørgensen et al., 2011; Weyl and Fabinger, 2013). Ten Kate and Niels (2005) and Weyl and Fabinger (2013) also discuss the cost pass-on to consumers in 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 of the above mentioned research or, to our knowledge, other research, has dealt with the question of to what extent oligopolistic firms pass the tax along to consumers when they have other goals beyond traditional profit maximization. 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

¹ Corrective taxes are also called ‘Pigouvian’ taxes, in honour of Arthur Pigou (Pigou, 1920) who first suggested the use of these taxes to internalise externalities. His work is often a standard reference in transport economics textbooks; see for example Button (2010).

the transport sector. Also, how the effects of taxes vary with different forms of imperfect competition between transport operators who are not pure profit maximisers and in particular how intensely 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).² 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).

Welfare impacts from taxation can be assessed according to the incidence of a tax, defined as the ratio of the tax borne by consumers to that borne by producers, which in turn depends on the pass-on rate (Weyl and Fabinger, 2013). In this paper we find the pass-on rate from producers to consumers within different market settings and a weighted producer's goal function in the transport sector. This has important implications for policy makers and practitioners interested in understanding the welfare impacts of a tax.

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

² 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.

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.

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 (passengers, tonnes, 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 $\frac{\partial P^*}{\partial t} \geq (<)1$ 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 Perfect 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 since the 1980s³, although perhaps not as much as it would have been expected (see Blauwens et al., 2008).

³ 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

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) or Weyl and Fabinger (2013):

$$\frac{dP^*}{dt} = \frac{E_S}{E_S - E_D} \quad \text{where} \quad E_S = \frac{dS(P)P}{dP X}, E_D = \frac{dD(P)P}{dP X} \quad (1)$$

E_S and E_D , thus, 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 (higher E_S) and the more inelastic the demand (lower E_D in absolute value) and vice versa. If, for example, $E_D = -0.8$ and $E_S = 0.6$, $\frac{\partial P^*}{\partial t} = 0.43$, transport users in this case pay 43% and suppliers pay 57% of the tax increase. In the special cases when the elasticity of supply tends to infinity or the elasticity of demand tends to zero, the users bear all the tax burden. Weyl and Fabinger (2013) expand these results and find the formula for the incidence of a finite tax change (rather than an infinitesimal change). This is obtained by replacing the pass-on rate by its quantity-weighted average over the range of the tax change.

2.3 One supplier (monopoly)

A monopoly is a market structure that has only one seller who offers a product or service with no close substitutes. 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

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.

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 Ten Kate and Niels, 2005):⁴

$$\frac{dP^*}{dt} = \frac{X_p(P)}{2X_p(P) + X_{pp}(P)(P^* - C_X(X) - t) - C_{XX}(X)X_p^2(P)} > 0 \quad (2)$$

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, $\frac{dP^*}{dt} < 1/2$, 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 ($(P^* - C_X - t) > 0$), the cost function is linear and the demand function is convex ($X_{pp} > 0$), $\frac{dP^*}{dt} > 1/2$, and the firm will always pass-on more than half of the tax to users.⁵ Fourth, when both the demand and cost functions are convex, $\frac{dP^*}{dt} \geq (<)1/2$; and so the firm may pass-on more than, just, or less than half of the tax.

Weyl and Fabinger (2013) extend the analysis of pass-on rates in a monopoly setting to include log-convex and log-concave demand functions and highlight that a monopolist pass-on rate under linear cost actually exceeds 1 when the demand is log-convex. They cite Seade (1985) and Bulow and Pfleiderer (1983) as the pioneers of this finding. Also, like they do for perfect competition, Weyl and Fabinger (2013) also expand the result for non-infinitesimal

⁴ Here and throughout the paper $X_p = \frac{dX}{dP}$, $X_{pp} = \frac{d^2X}{dP^2}$ etc.

⁵ 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 $\frac{dP^*}{dt} = \frac{b}{b-1}$ and $\frac{dP^*}{dt} = 1$, respectively, given a linear cost function.

tax changes. The relevant average pass-on rate in a monopoly is the markup-weighted average pass-on taken over values of \bar{X} , where \bar{X} is the quantity of the good or service that exogenously entered the market and markup is defined as price minus marginal cost. The authors essentially consider the exogenous entrance into the market of a quantity of the good \bar{X} , and if X continues to denote the total quantity sold in the market, the monopolist now only sells $X - \bar{X}$.

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 Europe, for example, one or two suppliers on many routes are commonplace in air transport, 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 Great Britain most train routes are served by one or two companies. These are franchises from the government to private operators to serve specific routes.⁶

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.⁷ Taking the results in Ten Kate and Niels (2005), Carlton and Perloff (2005) and Clark et al. (2009) 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), $\frac{dP^{*C}}{dt} = \frac{N}{N+1}$, where P^{*C} is the Cournot equilibrium price. The value of $\frac{dP^{*C}}{dt}$ increases with N but is always below 1.

This means that the pass-on rate to transport users increases as the number of

⁶ Some standard-class train fares are regulated by the government in Great Britain. These are typically commuter tickets for travel at peak times.

⁷ 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. Weyl and Fabinger (2013) provide a comprehensive analysis of pass-on rates and tax incidence in virtually all possible market settings.

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), the pass-on rate is $\frac{dP^{*S}}{dt} = \frac{2N-1}{2N}$ where P^{*S} is the equilibrium price. Also for the Stackelberg case the pass-on rate to transport users increases as the number of firms increase; for example, when $N = 2$ and $N = 3$, $\frac{dP^{*S}}{dt}$ is $3/4$ and $5/6$, respectively. For a given number of competitors, the pass-on rate is always higher under Stackelberg competition than under Cournot competition.
- 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.
- The equilibrium price under sequential fare competition (P^{*L}) is the same as under Bertrand competition ($P^{*B} = P^{*L}$) and the transport firms will pass all the tax along to users; that is, $\frac{dP^{*L}}{dt} = 1$.

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 and Stackelberg competition with linear demand and cost functions and homogenous transport services, the firms will pass more than half of the tax along to users. For a given number of suppliers the pass-on rate is higher under Stackelberg competition than under Cournot competition. Moreover, as the number of suppliers increases they will pass-on more of the tax to consumers. The latter 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. The marginal cost faced by a producer

consists of the production cost (c) and the tax that must be paid (t). If a firm attempts to undercut the rival and pass on a lower tax than the unit tax it must pay, then it will supply the entire market whilst the other firm(s) will have no demand; however it will make a loss on each unit sold. Attempting to sell at a price higher than the marginal production cost plus tax will lead to other firms undercutting and a demand of zero. Neither of these actions can be an equilibrium and hence the equilibrium is achieved when all firms pass on the entire tax. Note that it is the discontinuity of the demand function facing each firm that drives the results here.

The same situation occurs under perfect competition when the supply curve is flat or the demand curve is vertical. In intermediate cases atomistic behavior by firms leads to a market equilibrium in which only a fraction of the tax is passed on to consumers. At market level an increase in the total marginal cost to the producers leads to lower product demand and lower supply. The amount of the tax that can be passed on to consumers is higher when the demand is less elastic; in this case the price to consumers increases substantially and the share of tax left to be paid by suppliers is relatively small. This is also the case when supply is elastic. When demand is more elastic the tax burden on the suppliers tends to be larger. Note that this conclusion is contingent on all suppliers producing identical services. If not, our later analysis shows that price competition does not necessarily imply full pass-on to consumers, even though the firms maximise profits, see Figure 1.

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 that produce 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 tax pass-on rates and changes in quantity transported caused by 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 functions. 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 order to get tractable mathematical expressions for the demand functions and for consumer surplus, we assume, in line with Sing and Vives (1984), 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 transport firm 2, X_2 , in the following way:

$$U(X_1, X_2) = X_1 + X_2 - \frac{(X_1^2 + 2sX_1X_2 + X_2^2)}{2} \quad (3)$$

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 (decreases in absolute terms), the degree of complementarity between the services decreases, when $s > 0$ and increases the services become closer substitutes. The highly used utility function above implies, thus, that the degree of competition between the firms can be described in a simple way by the value of s .

Transport firms can be substitutes in one market and complements in another market. For example, when transport firms offer transport services between the same destinations they produce substitute services and the more similar (or substitutable) the services are the higher the value of s . Two bus companies running services with similar characteristics along the same routes are substitutes. These two same bus companies may be complements in another market. For example, some inter-city routes may be offered by just one of the two firms, and some routes may not be financially viable so there may be points of interchange. In that case, passengers would travel from A to B by one company and then transfer to another bus run by the other company, and travel from B to C. Other examples of complementarity in transport include trains and buses, some routes (intra and inter-city) are only covered by trains, whereas others are only covered by buses. Passengers flying to and from airports typically need to travel to and from the airport, and this is not done by plane but rather by some surface transport mode. Moreover, due to the well established hub-and-spoke networks airlines may produce complement services on some routes and substitute services on other routes.

When ignoring the income effect,⁸ 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

⁸ When there are no income effects, Equivalent Variation = Compensating Variation = change in Consumer Surplus. When there *are* income effects, Willig (1976) shows that change in consumer

provided by firm i and $i=1,2$. The consumer surplus' maximisation yields the following direct demand functions for the two services:

$$X_1 = \frac{1}{1+s} - \frac{P_1}{1-s^2} + \frac{sP_2}{1-s^2}, X_2 = \frac{1}{1+s} - \frac{P_2}{1-s^2} + \frac{sP_1}{1-s^2} \quad (4)$$

Inverting the demand system in (4) yields the following inverse demand functions

$$P_1 = 1 - X_1 - sX_2, \quad P_2 = 1 - X_2 - sX_1 \quad (5)$$

The transport firms, thus, produce symmetrically differentiated services.⁹ 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^* :

$$CS^* = \frac{X_1^{*2} + X_2^{*2} + 2sX_1^*X_2^*}{2} \quad (6)$$

Moreover, 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, π_i , ($i = 1,2$):

surplus can be used to estimate the (unobservable) compensating and equivalent variations and shows that in most applications the error of the approximation is very small. The error depends on (a) the ratio of the absolute value of consumer surplus to consumer's initial income (which can be interpreted as a measure of proportional change in real income due to a price change), which in most applications, he argues, is very small and (b) the income elasticity of demand, which in most cases is close to 1.

⁹ 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).

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

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):

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

In (9) we assume that both firms have the same objective function (same value of β) and that both are concerned about users' consumer surplus (CS), including that of those users that choose the rival firm's services. This is a reasonable assumption when both transport operators serve the same population and when local businesses and local authorities have substantial equity interest in them.

When $\beta = 0$ the firms are pure profit maximisers and 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.¹⁰ 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. First, the more power the managers have compared to the owners (Williamson, 1974), the less likely it is that the companies will be concerned about total consumer surplus because their status and reputation among users are dependent on how users evaluate their services compared to those of their rivals. Second, if the firms are international transport companies with different countries of registration it is unlikely that they will be concerned about the welfare of the rivals' users. Consequently, our goal function is most suitable when companies compete in a local, rather than an international, setting.

Nevertheless, 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).

¹⁰ It follows from equations (10) and (14) that equilibrium prices under Bertrand and collusion 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 (4), (6), (7) and (8) in (9) gives the following common equilibrium price P^{*B} and common equilibrium quantity X^{*B} for the firms:

$$P^{*B} = \frac{(1 - \beta)(c + t) + (1 - 2\beta)(1 - s)}{s(2\beta - 1) - (3\beta - 2)} \quad (10)$$

and

$$X^{*B} = \frac{(1 - \beta)(1 - c - t)}{(s(2\beta - 1) - (3\beta - 2))(1 + s)} \quad (11)$$

Simultaneous quantity competition (Cournot)

Under Cournot competition the transport operators maximise their objective functions by choosing the quantities they will supply. Using equations (5) to (9) gives the following common equilibrium price P^{*C} and common equilibrium quantity X^{*C} for the firms:

$$P^{*C} = \frac{(1 - \beta)(1 + s)(c + t) - \beta(2 + s) + 1}{s(1 - 2\beta) - (3\beta - 2)} \quad (12)$$

and

$$X^{*C} = \frac{(1 - \beta)(1 - c - t)}{s(1 - 2\beta) - (3\beta - 2)} \quad (13)$$

Collusion

When the firms collude they maximise a weighted sum of their total profit $(\pi_1 + \pi_2)$ and total consumer surplus (CS) ; that is, $S = (1 - \beta)(\pi_1 + \pi_2) + \beta CS$. Then we get the following equilibrium price P^{*COLL} and quantity X^{*COLL} for the firms:¹¹

¹¹ In this case the solutions are the same regardless of whether the firms use fare or quantity as their decision variable.

$$P^{*COLL} = \frac{(1 - \beta)(c + t) + 1 - 2\beta}{2 - 3\beta} \quad (14)$$

and

$$X^{*COLL} = \frac{(1 - \beta)(1 - c - t)}{(2 - 3\beta)(1 + s)} \quad (15)$$

Stability and existence conditions

The restrictions previously imposed on the values of s , β and $(c + t)$ secure that all numerators and denominators are positive in the expressions for equilibrium prices and quantities above, implying that $P^{*j}, X^{*j} > 0$, ($j = B, C, COLL$). These results will be used later on. Clark et al. (2009) also show that the bindings on s, β and $(c + t)$ are sufficient to conclude that interior equilibria exist for all competitive situations described above.¹²

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 $\partial X^{*j}/\partial C < 0$, $\partial X^{*j}/\partial \beta, \partial X^{*j}/\partial s > 0$ ($j = B, C, COLL$).

Before moving on to section 4, it should be highlighted that, from a mathematical point of view, because for Bertrand and for Cournot each firm maximises a weighted average of their own profits and the full consumer surplus, that consumer surplus counts twice. In the collusive case both firms maximise a weighted average of total profits plus the consumer surplus, and consumer surplus only enters the maximisation problem once. The reason for the difference in the maximisation problem set up is, as highlighted above, that each firm is concerned about users' consumer surplus, including the consumer surplus of those users that choose the rival firm's services. Although this assumption is both reasonable and necessary, from a mathematical point of view, the comparison of the equilibrium solutions for Cournot and Bertrand with the collusive should be taken with caution.

4 Tax influence under mixed goals and for different competitive situations

¹² For a thorough discussion of stability conditions in oligopoly in general, see Sead (1980).

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:

$$\frac{\partial P^{*B}}{\partial t} = \frac{(1 - \beta)}{s(2\beta - 1) - (3\beta - 2)} \quad (16)$$

and

$$\frac{\partial P^{*C}}{\partial t} = \frac{(1 - \beta)(1 + s)}{s(1 - 2\beta) - (3\beta - 2)} \quad (17)$$

and

$$\frac{\partial P^{*COLL}}{\partial t} = \frac{(1 - \beta)}{2 - 3\beta} \quad (18)$$

Under the restrictions placed on the values of β and s 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 β) 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 $\beta \leq 0.5$, 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 $\frac{\partial P^{*C}}{\partial t} \leq (>) 1$ when $s \leq (>) \frac{1-2\beta}{\beta}$. This condition implies that operators will always pass-on less than the tax amount to consumers when they produce complementary services; that is, $\frac{\partial P^{*C}}{\partial t} < 1$ when $s < 0$. The same is the case when they only put weight on profits ($\beta = 0$). Only when the firms produce substitute services ($s > 0$) and are not pure profit maximisers ($\beta > 0$) can the pass-on rate be higher than 1 (but not exceed 2) and the more fiercely the

firms compete, the higher the pass-on rate is. In the special case when the firms put equal weight on profits and consumer surplus ($\beta = 0.5$) the pass-on rate is unambiguously higher than 1 when they produce substitute services ($s > 0$).¹³

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

$$\frac{\partial P^{*C}}{\partial t}, \frac{\partial P^{*B}}{\partial t} > \frac{\partial P^{*COLL}}{\partial t} \text{ when } s > 0 \text{ and } \beta < 0.5$$

$$\frac{\partial P^{*C}}{\partial t} > \frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = 1 \text{ when } s > 0 \text{ and } \beta = 0.5$$

$$\frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = \frac{\partial P^{*C}}{\partial t} \text{ when } s = 0$$

$$\frac{\partial P^{*C}}{\partial t} < \frac{\partial P^{*B}}{\partial t} < \frac{\partial P^{*COLL}}{\partial t} \text{ when } s < 0 \text{ and } \beta < 0.5$$

$$\frac{\partial P^{*C}}{\partial t} < \frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = 1 \text{ when } s < 0 \text{ and } \beta = 0.5$$

When the transport operators produce substitute services ($s > 0$), 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 highest under Cournot competition but equal to 1 both when the firms collude and when they compete in fares. Users bear a higher (lower) burden of the tax under Bertrand competition than under Cournot competition when $s > (<) \frac{\beta}{1-2\beta}$. Consequently, the more intensely the firms compete (s increases) and the lower weight they put on consumer surplus (β decreases), the more likely it is that users are more penalised when the firms compete in prices than quantities, given that they produce substitute services.

Some of the conclusions above are reversed when the firms produce complementary services ($s < 0$). When they put less weight on consumer surplus than profits ($\beta < 0.5$) 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 ($\beta = 0.5$).

¹³ The fact that the pass-on rate under Cournot can be higher than 1, is verified in Delipalla and Keen (1992, p356) when the firms produce homogeneous services.

Note that the above conclusions differ to some extent from the literature review results in section 2 in which we concluded that the pass-on rates under Cournot competition are always lower than one and equal to one under Bertrand competition. The main reason for this is that in the literature review it is assumed that all the firms produce identical services and are profit maximisers, whilst our model assumes they produce symmetrical differentiated services and may have other goals on top of profit maximisation.

Moreover, after some mathematical manipulation we get the following cross derivative expressions using equations (16), (17) and (18):

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

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

$$\frac{\partial^2 P^{*C}}{\partial t \partial \beta} = \frac{(1 + s)^2}{[s(1 - 2\beta) - (3\beta - 2)]^2} > 0 \text{ when } s < 1 \quad (21)$$

$$\frac{\partial^2 P^{*C}}{\partial t \partial s} = \frac{(1 - \beta)(3 - 5\beta)}{[s(1 - 2\beta) - (3\beta - 2)]^2} > 0 \quad (22)$$

$$\frac{\partial^2 P^{*COLL}}{\partial t \partial \beta} = \frac{1}{[2 - 3\beta]^2} > 0, \quad \frac{\partial^2 P^{*COLL}}{\partial t \partial s} = 0 \quad (23)$$

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 (higher β). Also, given that the firms do not collude, the less complementary the services the firms produce are or the more intensely the firms compete (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 (Bertrand) and weigh profit and consumer surplus equally ($\beta = 0.5$).¹⁴ Finally, when the firms collude, the pass-on rate is, as

¹⁴ The nominator in (20), $(1 + \beta(2\beta - 3))$, is zero when $\beta = 0.5$.

expected, just as much unaffected by the value of s or the demand relationship between their services.

Using equations (16), (17) and (18) the pass-on rates when the firms compete in fares, in quantities and when they collude are shown graphically 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 ($\beta = 0.3$)¹⁵ and when they weigh profits and consumer surplus equally ($\beta = 0.5$).

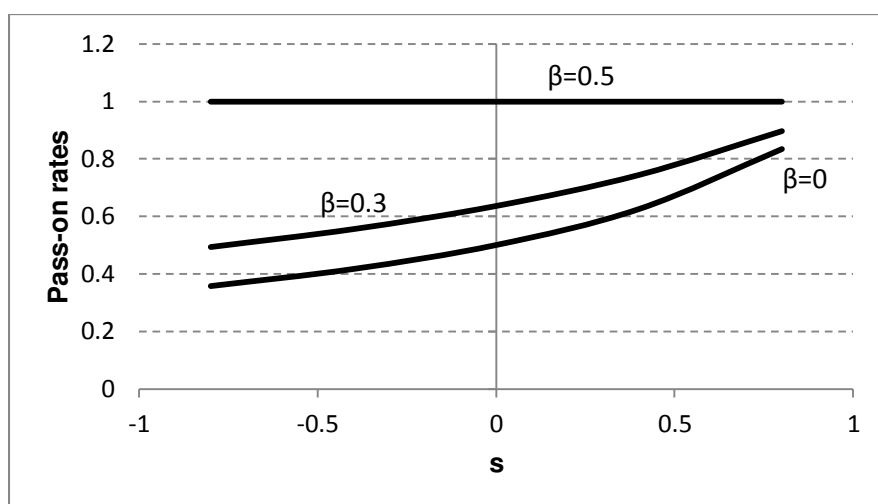


Figure 1. Tax pass-on rates from the firms when they compete in fares.

¹⁵ When $\beta = 0.3$, $(1-\beta) = 0.7$ and the firms weigh profits 2.3 times higher than consumer surplus.

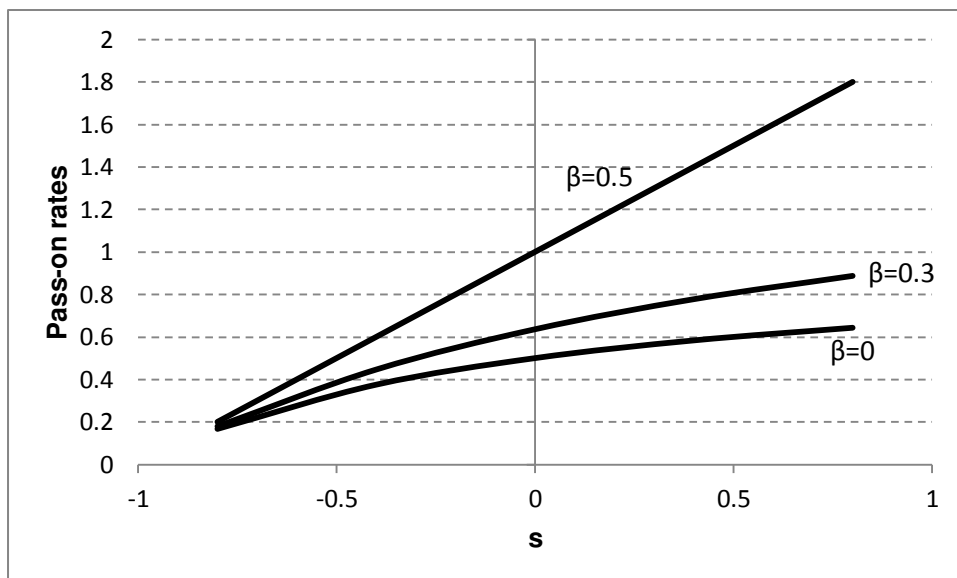


Figure 2. Tax pass-on rates from the firms when they compete in quantities.

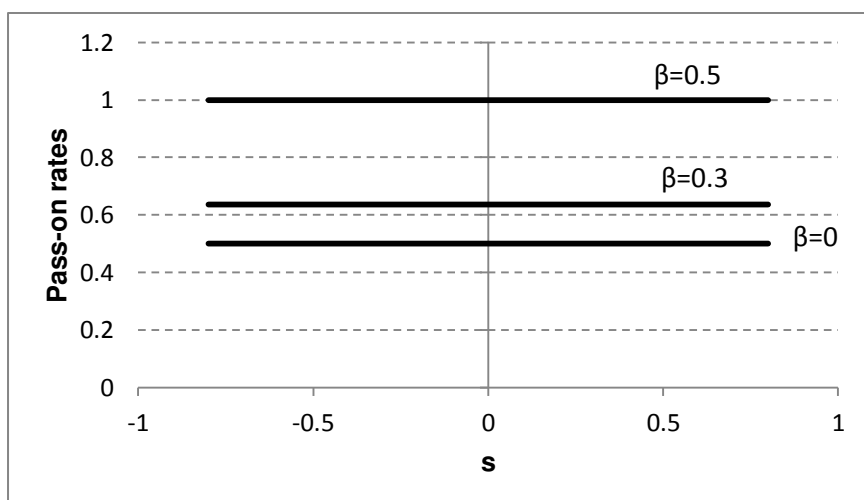


Figure 3. Tax pass-on rates from the firms when they collude.

The figures above support previous conclusions; the higher the weight the firms put on consumer surplus relative to profits (higher β) 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 substitute (complementary) services the pass-on rates are higher (lower) when they compete than when they collude. Additionally, Figure 1 and Figure 2 show that the pass-on rates under Bertrand (Cournot) competition increase convexly (concavely) with s when

$\beta < 0.5$. 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).¹⁶ 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 the 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

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

and

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

All derivatives 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

¹⁶ 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 more 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.

consumer surplus and their competitive environment. A further inspection of the derivatives above makes it possible to verify the following ranking:

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

$$\frac{\partial 2X^{*C}}{\partial t} > \frac{\partial 2X^{*B}}{\partial t} \text{ for } 0 < s < \frac{\beta}{1-2\beta}, \frac{\partial 2X^{*C}}{\partial t} < \frac{\partial 2X^{*B}}{\partial t} \text{ elsewhere}$$

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

$$\frac{\partial 2X^{*B}}{\partial t} = \frac{\partial 2X^{*COLL}}{\partial t} = \frac{\partial 2X^{*C}}{\partial t} \text{ when } s = 0$$

$$\frac{\partial 2X^{*C}}{\partial t} > \frac{\partial 2X^{*B}}{\partial t} > \frac{\partial 2X^{*COLL}}{\partial t} \text{ when } s < 0 \text{ and } \beta < 0.5$$

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

When all the 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 less negative impact on the total number of units transported when they collude than when they compete in either prices or quantities and produce substitute services ($s > 0$). Moreover, when the firms produce substitute services to a moderate degree, implying that $0 < s < \frac{\beta}{1-2\beta}$, the tax has less negative impact on the total number of units transported when they compete in quantities rather than prices. When they weigh profit and consumer surplus equally ($\beta = 0.5$) the tax has, however, 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 $\beta < 0.5$ some of the conclusions above are reversed; the tax influence on the total number of units transported is highest when the firms collude 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 the 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

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

$$\frac{\partial^2 2X^{*B}}{\partial t \partial s} = \frac{2(1-\beta)[(1-\beta) + 2s(2\beta-1)]}{[(s(2\beta-1) - (3\beta-2))(1+s)]^2} \geq (<) 0 \text{ when } s \leq (>) \frac{1-\beta}{2(1-2\beta)} \quad (28)$$

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

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

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

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 β) 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 β . Also when the firms compete in quantities and weigh profits more than consumer surplus ($\beta < 0.5$), increasing s leads to the tax having a lower negative impact on the total number of units transported. When the firms, however, weigh profit and consumer surplus equally ($\beta = 0.5$), the reduction in the total number of units transported due to a tax increase is unaffected by the value of s .¹⁷ Finally, it follows from equation (28) that when the firms compete in prices a per unit tax will have lower (higher) negative influence on the quantity transported when s increases, given that $s < (>) \frac{1-\beta}{2(1-2\beta)}$. 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

¹⁷ The nominator in (30) is zero when $\beta = 0.5$.

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 β) the more likely it is that the impact of the tax on the total number of units transported will be higher when s increases.

4.3 Summary of the most important results

Tables 1 and 2 summarise the most important assumptions and results.

Table 1: Most important assumptions of the model

Consumers' utility function	$U(X_1, X_2) = X_1 + X_2 - \frac{(X_1^2 + 2sX_1X_2 + X_2^2)}{2}$
Firms produce symmetrically differentiated services	$\frac{\partial X_1}{\partial P_2} = \frac{\partial X_2}{\partial P_1} = \frac{s}{1 - s^2}$
Firms' objective function when they compete	$WS_i = (1 - \beta)\pi_i + \beta CS \quad i = 1, 2, \quad \beta \leq 1/2$
Firms' objective function when they collude	$WS = (1 - \beta)(\pi_1 + \pi_2) + \beta CS$
Firms' costs functions	$C_i(X_i) = (c + t)X_i, \quad i = 1, 2, \quad 0 < (c + t) < 1$

Table 2: Comparison of the impact of a per unit tax (t) on price and quantity for Cournot, Bertrand and Collusion for different degrees of substitutability between the services (s) and different weights on consumer surplus and profits (β)

Degree of competition and firms' goals	Effect on quantities compared	Effect on prices compared
$s < 0$ and $\beta < 0.5$	$\frac{\partial 2X^{*C}}{\partial t} > \frac{\partial 2X^{*B}}{\partial t} > \frac{\partial 2X^{*COLL}}{\partial t}$	$\frac{\partial P^{*C}}{\partial t} < \frac{\partial P^{*B}}{\partial t} < \frac{\partial P^{*COLL}}{\partial t}$
$s > 0$ and $\beta < 0.5$	$\frac{\partial 2X^{*C}}{\partial t}, \frac{\partial 2X^{*B}}{\partial t} < \frac{\partial 2X^{*COLL}}{\partial t}$	$\frac{\partial P^{*C}}{\partial t}, \frac{\partial P^{*B}}{\partial t} > \frac{\partial P^{*COLL}}{\partial t}$ $\frac{\partial P^{*C}}{\partial t} > \frac{\partial P^{*B}}{\partial t}$ <p>when $0 < s < \frac{\beta}{1 - 2\beta}$,</p> $\frac{\partial P^{*C}}{\partial t} < \frac{\partial P^{*B}}{\partial t} \text{ elsewhere}$
$s > 0$ and $\beta = 0.5$	$\frac{\partial 2X^{*C}}{\partial t} < \frac{\partial 2X^{*B}}{\partial t} = \frac{\partial 2X^{*COLL}}{\partial t}$	$\frac{\partial P^{*C}}{\partial t} > \frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = 1$
$s < 0$ and $\beta = 0.5$	$\frac{\partial 2X^{*C}}{\partial t} > \frac{\partial 2X^{*B}}{\partial t} = \frac{\partial 2X^{*COLL}}{\partial t}$ $\frac{\partial 2X^{*C}}{\partial t} > \frac{\partial 2X^{*B}}{\partial t} \text{ for}$ $0 < s < \frac{\beta}{1 - 2\beta}$ $\frac{\partial 2X^{*C}}{\partial t} < \frac{\partial 2X^{*B}}{\partial t} \text{ elsewhere}$	$\frac{\partial P^{*C}}{\partial t} < \frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = 1$
$s = 0$ for all possible values of β	$\frac{\partial 2X^{*B}}{\partial t} = \frac{\partial 2X^{*COLL}}{\partial t} = \frac{\partial 2X^{*C}}{\partial t}$	$\frac{\partial P^{*B}}{\partial t} = \frac{\partial P^{*COLL}}{\partial t} = \frac{\partial P^{*C}}{\partial t}$

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 perfect competition (monopoly) are critically dependent on the shapes of the supply (cost) and demand functions. Under Bertrand and sequential price competition the firms pass the entire tax on to users whilst the pass-on rates under quantity competition are lower than one. The firms will pass on more of the tax to the users under Stackelberg competition than under Cournot competition and the pass-on rate increases in both cases with the number of competitors. It is worth noting that even profit maximising monopolists do not necessarily pass-on all the tax to users and given linear costs and demand functions they always pass half of the tax on to the users, which is less than the fraction that firms under all types of imperfect competition pass-on.

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 substitutability 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. Only when the firms produce independent services ($s = 0$) the pass-on rates are the same for all three market structures described here.

When the firms produce substitute services ($s > 0$) and place a higher weight on profits than on consumer surplus ($\beta < 0.5$) the pass-on rates are lowest when they collude. Whether Cournot competition or Bertrand competition yields the highest pass-on rate is ambiguous. It depends on the relative magnitudes of s and β : the less fiercely the firms compete (low but positive s) and the more weight they place on consumer surplus (high β) the more likely it is that the pass-on rates will be higher under Cournot. 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 the firms collude and compete in prices and higher than 1 when they compete in quantities.

Also when the firms produce complementary services ($s < 0$), the pass-on rates for Bertrand and collusion are the same and equal to 1 when the firms put equal weight on profits and consumer surplus ($\beta = 0.5$). When the firms place less weight on consumer surplus than profits ($\beta < 0.5$), consumers are less penalised when the firms compete in quantities and most penalised when they collude.

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 (β increases), regardless of whether they compete in prices, in quantities or collude. Since equilibrium prices always decrease when β 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 are not 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.

When the transport firms compete in quantities increasing s leads to lower 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 β . 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 (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. 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 wrong. The intuition behind these results is that the firms' marginal cost (including taxes) have a greater impact on their price setting the more fiercely they compete and the more weight they put on consumer surplus. 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 may also be wrong; if for example, their demand functions are linear and their cost functions are linear (convex) monopolists will pass on half (less than a half) of the tax to users (see section 2.3).

The model constitutes a first step in formalising the pass-on rate and impact on quantity transported of a per unit tax when oligopolistic transport firms maximise a weighted sum of profits and consumer surplus. One caveat of the model is that because firms that compete in prices or quantities care about the consumer surplus of all transport users, including those that choose the rival firm's services, the consumer surplus of all transport users enters two goal functions, so it counts twice, in contrast with the collusive case, where the consumer surplus of all transport users enters one goal function only, as the firms collude and act as one. The model also has a number of restrictive assumptions, the most important one being the linear set-up. The model could be extended to assess the impact of different pass-on rates on social welfare under different market structures and producers' goal functions. In particular, one may allow a richer non-linear demand function and possibly employ a conduct parameter on the lines of Weyl and Fabinger (2013) in order to obtain more general conclusions.

Our goal function allowed us to discuss the pass-on rate when transport firms put a different weight on profits compared to travellers' welfare and to make our analysis more general than analyses which assume transport firms are pure profit maximisers. This is in particular

important when analysing local transport markets where public owners often hold a substantial part of the transport suppliers' shares. On the other hand using a linear set-up and focusing on simultaneously competitive situations only limit the generality of the results.

Despite these limitations, the paper has nevertheless, established a model to discuss the transport users' burden of an output tax when the transport firms have goals that extend beyond profit maximation and produce transport services under competitive situations that are common as far as transport markets are concerned.

Acknowledgments: The authors thank Berner Larsen and Terje Mathisen at the Bodø Graduate School of Business and Derek Clark at University of Tromsø for helpful assistance and two anonymous referees for helpful comments. They are also grateful to Glen Weyl at the Department of Economics at University of Chicago for suggestions and ideas for future research.

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