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Commodity tax competition – purchases of spirits in the Scandinavian countries

Abstract:
A simulation model consisting of a representative consumer for each Scandinavian country is constructed and calibrated, in which consumers consume two goods: spirits and 'other goods'. Spirits is exposed to cross-border shopping, and the countries engage in tax competition. The equilibrium tax rates show large price differentials on spirits in Scandinavia. The findings also suggest that Norway and Denmark pay more attention to cross-border shopping and tax competition when setting the tax rates compared to Sweden. Furthermore, the equilibrium tax rates are rather robust with respect to the type of game that we consider, due to the fact that the utility maximizing tax rate for each country is rather insensitive with respect to other countries' tax rates. Nevertheless, the sequential game equilibrium consists of somewhat higher taxes and utility levels for each country compared to the simultaneous game equilibrium, meaning that the former equilibrium Pareto-dominates the latter.

Keywords: indirect taxes, excise taxes, cross-border shopping, commodity tax competition, alcohol, spirits, optimal taxation

JEL classification: C7, D12, H1, H31

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1 Introduction

The impact of cross-border shopping should be taken into consideration when setting tax rates. Cross-border shopping is costly from a nation's perspective because resources are lost through tax leakage. This will affect the maximizing tax rate wether the objective of the government is tax revenue- or welfare maximization. In addition, cross-border shopping opens up for strategic interaction among countries with respect to the tax rates, i.e., commodity tax competition. The outcomes of such games are defined as the equilibrium tax rates.

Cross-border shopping is widespread in the Scandinavian countries, e.g. with spirits.[1] High price differentials create large incentives for crossing the border. In recent years there has been a growing public debate in all the Scandinavian countries related to certain cross-border exposed goods. As a result, we have observed some cases of tax cut on spirits.[2] The justification has been related to cross-border shopping. In light of this, it brings to mind the question: To what extent are the actual tax rates on spirits in the Scandinavian countries consistent with the notion that the governments are taking into account cross-border shopping and tax competition? To try answering this question an empirically based simulation model is constructed and calibrated, with the purpose of finding equilibrium tax rates on spirits for the Scandinavian countries.

For each of the three countries we consider a representative consumer consuming two goods: Spirits and an aggregate good termed 'other goods' consisting of all other goods and services, i.e., we consider a complete demand system. Spirits is exposed to cross-border shopping and is purchased at home or abroad. We assume that the governments want to maximize utility, taking into account that there exists some negative externality associated with consumption of spirits. The purchase of registered and cross-border shopped spirits is included in the utility function as two different goods acting as substitutes for each other. They generate different utility because of costs buried in the utility function. One possible interpretation of this modelling strategy is that it focuses on non-pecuniary transportation costs, i.e., physical and psychological stress associated with cross-border shopping[3]. An advantage of this kind of modelling is that we can use standard consumer theory, with all its properties applying.

Two types of games are considered. As a point of departure we make the

[1] The focus on spirits is motivated by the fact that for Norway this is among the goods with the highest cross-border shopping measured as share of total consumption. The same is valid for the other countries. Moreover, it is a harmfull externality generating good potensially exposed to a very high tax rate compared to other goods, including other alcoholic beverages and tobacco (see e.g. Aasness and Nygård, 2009; NOU 2003:17).

[2] Significant cuts in 2003 for Denmark and 2002 for Norway.

[3] See Aasness and Nygård (2009) for another application of this kind of modelling.

assumption that the countries participate in a simultaneous game, which is the most common assumption made in the literature. In addition, we make the assumption that the countries participate in a sequential game, in which Denmark set their tax rate in first period, influenced by the continental policy, followed by Sweden, and finally Norway. Rigidities in the political systems may cause countries to act in such a sequential way, e.g. uncertainty about how other countries may act can make countries adopt a 'wait-and-see' strategy. This could induce a domino effect that starts with the policy at the Continent, and then spread through rest of Scandinavia. In addition, if the outcome of the sequential game benefits all the participating countries compared to the simultaneous, it becomes even more interesting to consider because the former will Pareto-dominate the latter. Then the simultaneous game equilibrium does not seem reasonable. [4]

There exists a significant theoretical literature on commodity tax competition. A seminal paper is Mintz and Tulkens (1986), another important one is Kanbur and Keen (1993). Several other contributions exists such as Edwards and Keen (1996), Wildasin (1988), Lockwood (1993, 2001), Lockwood et al. (1994), Nielsen (2001), Oshawa (1999), Haufler and Schjelderup (2004), and Wang (1999). Common to these papers are the use of game theory and their preoccupation with characterizing different equilibria.[5] Turning to the empirical studies there are less contributions, but Rork (2003), Nelson (2002) and Devereux et al. (2007) are some examples. Common to these are the aim of estimating reaction function. Another common feature is that theory is not explicitly present when it comes to their empirical modelling. Theory is used only to shed some light over the empirical estimation. In the present paper a framework based on consumer theory and suitable for analyzing tax competition in the Scandinavian countries is presented, and an empirical model based explicitly on this theory is constructed. By providing a close link between the theory and the empirical model, we ensure that our empirical results are consistent with theory.

The simulations show that we are able to find equilibria. These indicate that large differences in price on spirits in Scandinavia may appear also

[4] The literatur has been dominated by the assumption of simultaneous games, without much problematization. Only few examples of the contrary can be given, such as Wang (1999). In the presentation 'And the tax winner is... Endogeneizing leadership in commodity taxation race' at the 65th Congress of the International Institute of Public Finance (IIPF), professor Rota-Graziosi showed that a sequential game could be the outcome of a two-stage game where the timing decision was taken in the first periode. His work was influenced by van Damme and Hurkens (1996, 2004) and Amir and Stepanova (2006), which considered this within the context of Industrial Organization. In our context, if all countries could gain from playing a sequential game compared to a simultaneous, the simultaneous game (Nash) equilibrium would not constitute a sub-game perfect equilibrium of a game in which the order of moves was determined in a pre-play stage.

[5] For papers adressing the impact of cross-border shopping on welfare optimal tax rates, but not within a game theoretical framework, see e.g. Christiansen (1994) and Scharf (1999).

within a tax competition context. The price differential between Norway and Sweden are even larger than in the base year 2004, suggesting that price differences in Scandinavia on spirits could increase as well as decrease in future. The tax rates in 2004 are, for each country, higher than the equilibrium tax rates. On the other hand, compared to a closed economy situation, the tax rates in 2004 are lower, although only slightly for Sweden. We show that this suggests that Norway and Denmark to a larger extent are taking into account cross-border shopping and tax competition when setting the tax rates. Furthermore, the results are rather insensitive with respect to the type of game, i.e., simultaneous or sequential. This is due to the fact that the utility maximizing tax rates are rather robust with respect to other countries' tax rates. Nevertheless, we end up with somewhat higher tax rates and prices in the sequential game and also a higher utility for every country.

The paper starts out by presenting the theoretical framework. Section 3 turns to the empirical model, describing the specification and the procedure of calibration. In Section 4 simulation results are presented. Finally concluding remarks are given in Section 5.

2 Theoretical framework

2.1 A consumer model with implicit transportation costs

In the model set up Norwegian consumers are cross-border shopping in Sweden, Denmark and other countries (e.g. Finland). Swedish consumers are cross-border shopping in Denmark and other countries (e.g. Germany), while Danish consumers only are cross-border shopping in other countries (e.g. Germany). This set up implies that the direction of cross-border shopping will be determined by our theoretical framework, which is based on the current situation. Consequently the model must be used carefully because we can end up with unreasonable equilibria.[6] Nevertheless, it will be suitable for finding equilibria where the direction of cross border shopping is the same as in the base year. The model consists of a representative consumer for each country, i.e. Norway, Sweden and Denmark. For Norway the utility of the representative consumer is given by

$$U^N(S_R^N, S_S^N, S_D^N, S_O^N, C^N), \tag{1}$$

where S_R^N is the registered purchase of spirits in Norway by Norwegians, S_S^N, S_D^N and S_O^N are Norwegians cross-border shopping in Sweden, Denmark and all other countries, respectively. C^N is the aggregate consumption of

[6] A country could end up with the lowest price (e.g. Norway), but still have outward cross-border shopping while no inward cross-border shopping.

all other goods and services. The consumer is supposed to maximize (1) subject to the budget constraint

$$p_R^N S_R^N + p_S^N S_S^N + p_D^N S_D^N + p_O^N S_O^N + p_C^N C^N = Y^N, \tag{2}$$

where p_R^N is the price of registered spirit consumption in Norway, and p_S^N, p_D^N and p_O^N are the prices facing Norwegians on spirits in Sweden, Denmark and other countries respectively. p_C^N is the price of the aggregate good and Y^N is the total expenditure of Norwegians. From this we can derive Marshallian demand functions

$$S_i^N \left(p_R^N, p_S^N, p_D^N, p_O^N, p_C^N, Y^N\right) \text{ for } i = R, S, D, O \tag{3}$$

$$C^N(p_R^N, p_S^N, p_D^N, p_O^N, p_C^N, Y^N) \tag{4}$$

i.e., consumption of spirits from different sources and consumption of the aggregate good as function of all prices and total expenditure. In the same way, for Sweden the utility of the representative consumer is given by

$$U^S(S_R^S, S_D^S, S_O^S, C^S), \tag{5}$$

which is maximized subject to the budget constraint

$$p_R^S S_R^S + p_D^S S_D^S + p_O^S S_O^S + p_C^S C^S = Y^S, \tag{6}$$

and hence we derive demand functions for Sweden

$$S_i^S \left(p_R^S, p_D^S, p_{O,}^S p_C^S\right) \text{ for } i = R, D, O \tag{7}$$

$$C^S(p_R^S, p_D^S, p_O^S, p_C^S). \tag{8}$$

Finally, for Denmark we have the representative utility

$$U^D(S_R^D, S_O^D, C^D), \tag{9}$$

which is maximized subject to the budget constraint

$$p_R^D S_R^D + p_O^D S_O^D + p_C^D C^D = Y^D, \tag{10}$$

yielding the demand functions for Denmark

$$S_i^D \left(p_R^D, p_O^D, p_C^D, Y^D\right) \text{ for } i = R, O \tag{11}$$

$$C^D(p_R^D, p_O^D, p_C^D, Y^D). \tag{12}$$

2.2 Governments' objective: utility maximization

Let t^N, t^S and t^D be the tax on spirits in Norway, Sweden and Denmark, respectively. The relationship between the tax rate, the consumer price and the pre-tax price is

$$p_R^j = q^j + t^j \text{ for } j = N, S, D, \tag{13}$$

where q^j is the (constant) pre-tax price of registered purchase of spirits in country j. We assume that the governments want to maximize the utility of the representative consumer, taking into account that there exists some external effects associated with consumption of spirits.[7] We start with finding the first best solution for this problem. If we take as a point of departure Sweden, we have

$$\max_{\mathbf{S},C} U^S(S_R^S, S_D^S, S_O^S, C^S) - \alpha^S \left(S_R^S + S_D^S + S_O^S\right) \tag{14}$$

$$\begin{aligned} s.t.\ p_R^S S_R^S + p_D^S S_D^S + p_O^S S_O^S + p_C^S C^S &= y^S + T^S & (15) \\ S_R^S t_R^S + C^S t_C^S - T^S &= \overline{R}^S - R_{CB}^S & (16) \end{aligned}$$

where t_C^S is the tax on the aggregate good, $\overline{R}^S$ is the revenue requirements, R_{CB}^S is the tax revenue collected from inward cross-border shopping (e.g. from Norwegians), and T^S is a lump sum transfer (or tax). α^S is associated with the external effect of spirits consumption. Substituting for T^S in (15) give us one constraint

$$y^S - \left(q_R^S S_R^S + p_D^S S_D^S + p_O^S S_O^S + q_C^S C^S\right) = \overline{R}^S - R_{CB}^S, \tag{17}$$

where q_R^S and q_C^S is the producer price of spirits and the aggregate good, respectively. Maximizing (14) subject to (17) gives the first order conditions

$$\frac{\partial U^S}{\partial C^S} = -\lambda q_C^S, \tag{18}$$

$$\frac{\partial U^S}{\partial S_R^S} - \alpha^S = -\lambda q_R^S\ , \tag{19}$$

and

$$\frac{\partial U^S}{\partial S_i^S} - \alpha_i^S = -\lambda p_i^S \text{ for } i = D, O, \tag{20}$$

where λ is the Lagrange multiplier.

[7] Tax revenue maximization is often used in the commodity tax competition literature. Simulation results with the governments having this as an objective is left for the appendix, see A.2.

With $\alpha = 0$ the first best solution will be a uniform tax structure. If we assume $\alpha < 0$ the first best solution would be to set an extra tax on spirits equal to -α/λ, i.e., fully internalize the external cost. First best requires that we can freely set the tax rate on all goods, including 'other goods' and those purchased abroad through cross-border shopping. Cross-border shopping is not taxable and we assume that the tax rate on 'other goods' is fixed. This implies that we end up in a second best world in which the government uses the tax on spirits to correct for the externalities, along with adjusting the transfers to satisfy the revenue constraint. To study the second best problem we formulate the maximization problem for Sweden as

$$\max_{p_R^S, T^S} V^S(p_R^S, p_D^S, p_O^S, p_C^S, y^S + T^S) - \alpha^S \left[S_R^S + S_D^S + S_O^S\right] \tag{21}$$

s.t.

$$S_R^S t_R^S + S_C^S t_C^S - T^S = R^S - R_{CB}^S, \tag{22}$$

giving the following first order conditions

$$\frac{\partial V^S}{\partial p_R^S} - \alpha^S \left[\frac{\partial S_R^S}{\partial p_R^S} + \frac{\partial S_D^S}{\partial p_R^S} + \frac{\partial S_O^S}{\partial p_R^S}\right] \tag{23}$$

$$-\lambda \left[S_R^S + t_R^S \frac{\partial S_R^S}{\partial p_R^S} + t_C^S \frac{\partial S_C^S}{\partial p_R^S} + \frac{\partial R_{CB}^S}{\partial p_R^S}\right] = 0,$$

$$\frac{\partial V^S}{\partial T^S} - \alpha^S \left[\frac{\partial S_R^S}{\partial T^S} + \frac{\partial S_D^S}{\partial T^S} + \frac{\partial S_O^S}{\partial T^S}\right] \tag{24}$$

$$-\lambda \left[t_R^S \frac{\partial S_R^S}{\partial T^S} + t_C^S \frac{\partial S_C^S}{\partial T^S} - 1\right] = 0.$$

By using Roy's identity in (24), substituting for $\partial V^S/\partial p_R^S$ in (23), and using the Slutsky equation these two first order conditions can be formulated as

$$t_R^S \frac{\partial \widehat{S}_R^S}{\partial t_R^S} + t_C^N \frac{\partial \widehat{S}_R^S}{\partial t_C^S} = \frac{-\alpha^S}{\lambda} \left[\frac{\partial \widehat{S}_R^S}{\partial t_R^S} + \frac{\partial \widehat{S}_D^S}{\partial t_R^S} + \frac{\partial \widehat{S}_O^S}{\partial t_R^S} + \right] - \frac{\partial R_{CB}^S}{\partial p_R^S} \tag{25}$$

where the hat indicates that we look at compensated demand. The left-hand side of the equation is known from optimal tax theory first derived by Ramsey. It is the change in compensated demand of registered spirits following a small intensification in tax on spirits and 'other goods'. The right hand side reflects the externality effect. In the special case of $\alpha = 0$ and $\partial R_{CB}^S/\partial p_R^S = 0$, the right-hand side reduces to zero. Then we should set the t_R^S such that in optimum a small intensification of the indirect tax system will not change the compensated demand for S_R^S. Further (25) can be rewritten as

$$\frac{t_R^S}{p_R^S} = -\frac{\alpha^S}{\lambda}\frac{\left(\frac{\partial \widehat{S}_R^S}{\partial t_R^S} + \frac{\partial \widehat{S}_D^S}{\partial t_R^S} + \frac{\partial \widehat{S}_O^S}{\partial t_R^S}\right)}{\frac{\partial \widehat{S}_R^S}{\partial t_R^S} p_R^S} - \frac{t_C^S}{p_C^S}\frac{El_{p_C^S}\widehat{S}_R^S}{El_{p_R^S}\widehat{S}_R^S} - \frac{\frac{\partial R_{CB}^S}{\partial t_R^S}}{\frac{\partial \widehat{S}_R^S}{\partial t_R^S} p_R^S} \tag{26}$$

By using Euler's theorem and the homogeneity of degree one of the expenditure function, we get

$$\begin{aligned} \frac{t_R^S}{p_R^S} &= \frac{t_C^S}{p_C^S}\left[\frac{El_{p_R^D}\widehat{S}_R^S + \frac{p_{CB}^S S_{CB}^S}{p_R^S S_R^S} El_{p_R^S}\widehat{S}_{CB}^S}{El_{p_R^D}\widehat{S}_R^S}\right] \\ &\quad -\frac{\alpha^S}{\lambda}\frac{1}{p_R^S}\left[\frac{El_{p_R^S}\widehat{S}_R^S + \frac{S_{CB}^S}{S_R^S} El_{p_R^S}\widehat{S}_{CB}^S}{El_{p_R^S}\widehat{S}_R^S}\right] - \frac{\frac{\partial R_{CB}^S}{\partial t_R^S}}{\frac{\partial \widehat{S}_R^S}{\partial t_R^S} p_R^S}, \end{aligned} \tag{27}$$

where

$$\frac{p_{CB}^S S_{CB}^S}{p_R^S S_R^S} El_{p_R^S}\widehat{S}_{CB}^S = El_{p_R^N}\widehat{S}_D^N \frac{p_D^N S_D^N}{p_R^N S_R^N} + El_{p_R^N}\widehat{S}_O^N \frac{p_O^N S_O^N}{p_R^N S_R^N},$$

$$\frac{S_{CB}^S}{S_R^S} El_{p_R^S}\widehat{S}_{CB}^S = El_{p_R^S}\widehat{S}_D^S \frac{S_D^S}{S_R^S} + El_{p_R^S}\widehat{S}_O^S \frac{S_O^S}{S_R^S}.$$

Note that the expression within the brackets in the first term of expression (27) will always be less or equal to one if we assume that the substitution between registered spirits and cross-border shopped spirits is zero or positive, i.e., $El_{p_R^S}\widehat{S}_{CB}^S \geq 0$. Under the assumption of $\alpha^S = 0$ and $\partial R_{CB}^S/\partial p_R^S = 0$, this implies that $t_R^S/p_R^S \leq t_C^S/p_C^S$, i.e. the optimal tax rate on spirits as share of consumer price, is always equal or below that of the aggregate good. When it is equal, i.e., under zero substitution to cross-border shopping, we have an uniform structure as in the first best. When cross-border shopping is prevalent we should deviate from the uniform structure and not tax spirits according to first best. Outward cross-border shopping is costly for the society and this must be balanced against the desire for minimizing the distortion between spirits and the aggregate good. If $\alpha^S > 0$ we have negative externalities which impacts the optimal tax rate. With no substitution to cross-border shopping we should tax according to first best, i.e., putting an extra tax on spirits equal to marginal external cost, -α^S/λ. Whenever we have substitution to cross-border shopping, the formula will differ from a first best situation. In the presence of substitution to cross-border shopping we will not set the externality correcting tax rate as high as -α^S/λ, i.e. we will not fully internalize the external cost. Outward cross-border shopping is costly and this must be traded off against the desire for internalizing.

If $\partial R_{CB}^S/\partial p_R^S \neq 0$ then effects on the inward cross-border shopping must also be taken into consideration. With $\partial R_{CB}^S/\partial p_R^S < 0$ the tax revenue collected from inward cross-border will tend to decrease the tax rate, and vice versa. Note that in this case we will not observe a uniform structure even if $\alpha^S = 0$ and with the assumption of no outward cross-border shopping.[8]

For Norway and Denmark the same optimization apply with only modest differences. Besides having more or less consumptions variables, the main difference is that Norway does not have any inward cross-border shopping.

Game theory Equation (27), and the corresponding conditions from the maximization for Norway and Denmark, implicitly define a reaction function for each country, i.e., the utility maximizing tax rate on spirits as a function of other countries' tax rate. If we write the utility as a function of tax rates only, namely $\widetilde{V}^j(t^N, t^S, t^D)$ for $j = N, S, D$, the equilibrium tax rates for the simultaneous game solves the equation

$$\frac{\partial \widetilde{V^N}}{\partial t^N} = \frac{\partial \widetilde{V^S}}{\partial t^S} = \frac{\partial \widetilde{V^D}}{\partial t^D} = 0, \tag{28}$$

and for the sequential game we have

$$\max_{t^N} \widetilde{V^N}(t^N, t^S, t^D), \tag{29}$$

i.e., Norway maximizes the utility taking Swedish and Danish tax rate as given. The solution to this problem gives the reaction function for Norway, i.e., the optimal Norwegian tax rate as a function of Swedish and Danish tax rates, namely $t^N(t^S, t^D)$. Sweden maximizes utility subject to the reaction function of Norway, taking the Danish tax rate as given, hence

$$\max_{t^S} \widetilde{V^S}(t^N, t^S, t^D) \tag{30}$$
$$s.t.\ t^N(t^S, t^D).$$

The solution to this problem implicitly give us the Swedish optimal tax rate as a function of the Danish tax rate set in the first period of the game, i.e. $t^S\left(t^D\right)$. Denmark maximizes utility subject to this and the reaction function for Norway

$$\max_{t^D} \widetilde{V^D}(t^N, t^S, t^D) \tag{31}$$
$$s.t.\ t^N\left(t^S, t^D\right) \text{ and } t^S(t^D).$$

The optimal Danish tax rate in equilibrium is given by the solution to this problem, and can be written as

$$\frac{\partial \widetilde{V^D}}{\partial t^D} + \left[\frac{\partial \widetilde{V^D}}{\partial t^N}\left(\frac{\partial t^N}{\partial t^S}\frac{\partial t^S}{\partial t^D} + \frac{\partial t^N}{\partial t^D}\right) + \frac{\partial \widetilde{V^D}}{\partial t^S}\frac{\partial t^S}{\partial t^D}\right] = 0 \tag{32}$$

.

[8] Recall that we are not able to freely choose the tax rate on 'other goods', as first best requires.

3 Simulation model

Based on the framework above a simulation model is constructed and calibrated. This section outlines the model specification and comments upon the calibration procedure.

3.1 Specification of preferences

The utility of the representative consumer for Norway, U^N, is specified as a two-level LES (see Aasness and Holtsmark, 1993), i.e.

$$
\begin{aligned}
U^N &= B^N(u^N - \gamma_a^N)^{\beta_a^N}(c^N - \gamma_c^N)^{\beta_c^N} \quad (33)\\
u^N &= B_s^N(S_R^N - \gamma_R^N)^{\beta_R^N}(S_S^N - \gamma_S^N)^{\beta_S^N}\left(S_D^N - \gamma_D^N\right)^{\beta_D^N}\left(S_O^N - \gamma_O^N\right)^{\beta_O^N}, \quad (34)
\end{aligned}
$$

where γ_a^N and γ_c^N are minimum consumption of total spirits and of the aggregate good respectively (i.e. minimum consumption at the top level) and γ_R^N, γ_S^N, γ_D^N, γ_O^N are the minimum consumption associated with total spirits consumption from different sources (i.e. minimum consumption at the bottom-level). The $\beta-$parameters are assumed to sum to one at each level and can then be interpreted as marginal budget shares, i.e., β_a^N and β_c^N is the marginal budget share of total spirit and of the aggregate good respectively, β_c^N, β_c^N and β_c^N are the marginal budgets shares (of total spirit consumption) of the spirits from different sources.

Since the above specification implies separability assumptions, we can represent the utility in terms of a utility tree. [9] The logic of the representative consumers decision problem can be illustrated by considering an increase in tax on registered spirits or on spirits purchased abroad. First the consumer will consider changing his composition with respect to where to purchase spirits. Then he will consider whether to change his total spirits consumption, i.e., the composition of spirits and the aggregate good. Finally he will run down the utility tree checking whether the consumption is optimally allocated.

The utility specification for Sweden and Denmark are exactly the same. Only note that in equations corresponding to (34) we will have fewer consumption variables.

3.2 Calibration procedure

The calibration procedure is developed in Aasness (1993).[10] Let the utility function have a vector Φ of unknown parameters. It can be shown that these

[9] For a general discussion of utility trees, see Deaton and Muellbauer (1980, ch.5). For an application, see Aasness and Nygård (2009).

[10] This method is greatly influenced by Frisch (1959).

unknown parameters can be identified from a set of characteristics of the demand function at one point . In other words a function f exist

$$\Phi = f(\mathbf{p},\ \mathbf{S},\ \mathbf{E}\ , C, Y, \sigma^T, \sigma^S), \tag{35}$$

where the arguments in the function are the characteristics, i.e., $\mathbf{p}$ is a vector containing all prices, $\mathbf{S}$ is a vector containing spirits consumption from different sources, $\mathbf{E}$ is a vector containing Engel elasticities for all goods, C is the consumption of the aggregate good, Y is the total expenditure, and finally σ^T and σ^S are two substitution parameters (minus the inverse of the flexibility of the marginal utility of money, cf. Frisch (1959)) associated with the top level and the bottom level respectively. Note that this method makes it possible to exploit information from various sources (both micro and macro data) in a consistent way.

National account data from 2004 give us total expenditure, consumption of registered spirits and the aggregate good measured in their respective currency. I convert to Norwegian kroner, such that every consumption variable is measured in Norwegian 2004-kroner.[11] Several sources have been used to make rough estimates on the amount of cross-border shopping in the different countries in 2004.[12]

For Norway we use the Engel elasticities for registered spirits from the governmental report on excise taxes and cross-border shopping (NOU 2003:17).[13] For Sweden I use as a source the work of Asplund et al. (2007). For Denmark I have not succeeded in finding a relevant estimate. When setting the value on this parameter I have taken into consideration the estimates of Norway and Sweden, in addition to the meta analysis of Gallet (2007). The Engel elasticities along with the budget shares in the base year are given in the tables 1-6, first two rows. Note that we use the same Engel elasticity on cross-border shopped spirits as that of the registered spirits. When we know the budget shares and all but one Engel elasticity, the last will follow from consumer theory, i.e., that of 'other goods'.

Finally the two substitution parameters are set on the background of a sensitivity analysis of the price elasticities it generates. We have in principle two degrees of freedom and can chose the value of two price elasticities. As shortly will be clear, we focus on two types of own price elasticities of spirits when calibrating the substitution parameters. When the model is calibrated the data fits the demand curves exactly, i.e., for the prices and

[11] Note that when measuring consumption in kroner, we actually do not need information about prices to derive the demand functions.

[12] For Denmark and Sweden these includes *Rapport om Grænsehandel, 2004* and data collected by the Swedish SoRAD. For Norway the sources inlude data collected by the Swedish Systembolaget and the Norwegian SIRUS, and corresponds to the data on cross-border shopping used in the model KONSUM-G in Statistics Norway.

[13] Additional sourches could be Alver (2004) and Selvanathan and Selvanathan (2007). They are all roughly in line with this.

total expenditure in the base year 2004, the model generates consumption patterns exactly fitting the data we use.

The tables 1-6 present matrixes of Cournot price elasticities generated by our calibrated model at the base year prices and total expenditure, where we have two different levels of aggregation. The tables 2, 4 and 6 is based on an aggregation of spirits, such that we end up with a 2x2 matrix. The tables 1,3 and 5 is the disaggregated one, namely a 5x5 matrix for Norway, a 4x4 matrix for Sweden and a 3x3 matrix for Denmark.[14]

Let us consider the tables 2, 4 and 6. We observe that the own price elasticity for total spirit demand is -0.94 for Norway, implying that a 1 percent increase in prices both at home and abroad will decrease total demand by 0.94 percent. This is in line with the elasticity used in NOU 2003:17, although slightly higher in absolute value. Almost the same value prevail for the corresponding elasticity for the two other countries, but spirits in Sweden is assumed to be somewhat less price sensitive than in Norway. Finally, spirit demand in Denmark is assumed to be even less price sensitive. Some support for this can be found in NOU 2003:17.[15]

Next turn to the tables 1, 3 and 5. The own price elasticity of registered spirits with respect to domestic price is significantly higher in absolute value compared to the corresponding total own price elasticities in the tables 2, 4, and 6. This reflects the fact that the representative consumer can substitute to cross-border shopping when the domestic price increases. The own price elasticity for registered spirits in Norway is -1.18. This is lower than in the NOU 2003:17 (-1.41), but more in line with the value used in the model KONSUM-G for 2007.[16] For Sweden the corresponding price elasticity is -1.31, which is in line with Asplund et al. (2007) (-1.29).[17] Finally the corresponding Danish elasticity is -1.42. In a report from 2007 calculations imply an assumption of the the corresponding price elasticity around -1.5 (*Grænshandelsrapport 2007*). Note that the differentials between the two price elasticities are by far largest for Denmark, then followed by Sweden and finally Norway. This can be interpreted as Denmark being more exposed to cross-border shopping than the other countries. When considering the

[14]By assuming that the prices within a group move in the same proportions, we can by exploiting Hicks composite commodity theorem aggregate all the goods within a certain group and threat this as one commodity. Consequently, note that the column sums in the tables are zero. These are weighted sums of the elasticities which follows from the consumers budget constraint. In the same way all the row sums are zero in prices and total expenditure. This is a consequence of the fact that all the demand function are homogenous of degree zero in prices and total expenditure. In practice, this can be very usefull to for instance avoid programming faults.

[15]Actually, since there exits large price differential between the countries with respect to spirits, it seems natural to think of the good as being a more luxory good in the high price country. In other words letting the Engel - and price elasticity tending to increase when prices increases.

[16]KONSUM-G is a consumer model at Statistics Norway.

[17]In addition, see SOU 2004:86, pp. 220-221, for a discussion.

geography and the distance to the German border for the Danish citizens, this seems defendable. Furthermore, both Sweden and Norway have high population density near the border. But, the possibility of cross-border shopping is more restricted in Norway than in Sweden through quotas. It seems possible that this could restrain the effect of a price change somewhat.

Even when the demand functions are calibrated it still remains some calibration of parameters before we can proceed with simulation tasks. We must have knowledge about the tax rates in 2004 to calibrate producer prices in the base year. We also need information about the consumer prices on spirits to determine wether the equilibria are reasonable. Tax rates and prices on spirits is found in WHO (Global Status Report on Alcohol, 2004).[18] In addition we must have the tax rate on the aggregate good. This is set to be equal to the general VAT level in the country. This is of course a rough estimate, but the VAT constitute the major source of indirect taxation in general. Some goods are taxed more heavily and some more leniently, but it seems reasonable that this roughly average out.

Furthermore we need to have some opinion about the external costs of alcohol consumption. The value of this parameter is set on the bases of Gjelsvik (2004) (for Norway), Jar et al.(2002) (for Sweden) and the report of 'Sunnhetsministeriet' (1999) (for Denmark). These studies give an estimate on the total costs of alcohol consumption in the three countries. We are focused on spirits. How much spirits contributes to total costs is determined by how much of the total consumption of pure alcohol spirits contributes to. Thereby implicitly assuming that one liter of pure alcohol is equally damaging across different types of beverages.

Table 1. Price elasticities, Engel elasticities (E), budgets shares (w), and tax rates (t/q) for Norway - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chn	ej.03casn	ej.03cadn	ej.03can	ej.ogn	sum
c03chn	Spirits; Norway	0,603	1,569	2,204	-1,183	0,139	0,076	0,025	-0,627	0,000
c03casn	Spirits; cross-border shopping Sweden	0,036	1,569	0,000	1,267	-2,311	0,076	0,025	-0,627	0,000
c03cadn	Spirits; cross-border shopping Denmark	0,012	1,569	0,000	1,267	0,139	-2,374	0,025	-0,627	0,000
c03can	Spirits; cross-border shopping other countries	0,066	1,569	0,000	1,267	0,139	0,076	-2,425	-0,627	0,000
cogn	Other goods and services	99,282	0,996	0,240	0,000	0,000	0,000	0,000	-0,995	0,000
	sum (weighted)	100 %	1,000		0,000	0,000	0,000	0,000	0,000	

Table 2. Price elasticities for Norway - main groups

codes	Commodity groups	ej.03cn	ej.ogn	ej.sum
c03cn	Spirits	-0,942	-0,627	0,000
cogn	Other goods and services	0,000	-0,995	0,000
	sum (weighted)	0,000	0,000	

[18] The data are from 2002. For Sweden the tax rate did not change significantly from 2002 to 2004. Norway have lowered their tax rate some, and the Danish tax rate was substansially decreased in late 2003. The data have been adjusted for these facts.

Table 3. Price elasticities, Engel elasticities (E) and budgets shares (w) for Sweden - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chs	ej.03cads	ej.03cas	ej.ogs	sum
c03chs	Spirits; Sweden	0,536	1,409	2,799	-1,310	0,365	0,098	-0,562	0,000
c03cads	Spirits; cross-border shopping Denmark	0,059	1,409	0,000	0,890	-1,835	0,098	-0,562	0,000
c03cas	Spirits; cross-border shopping other countries	0,220	1,409	0,000	0,890	0,365	-2,102	-0,562	0,000
cogs	Other goods and services	99,185	0,997	0,250	-0,001	0,000	0,000	-0,995	0,000
	sum (weighted)	100 %	1,000		0,000	0,000	0,000	0,000	

Table 4. Price elasticities for Sweden in - main groups

codes	Commodity groups	ej.03cs	ej.ogs	ej.sum
c03cs	Spirits	-0,847	-0,562	0,000
cogs	Other goods and services	-0,001	-0,995	0,000
	sum (weighted)	0,000	0,000	

Table 5. Price elasticities, Engel elasticities (E) and budgets shares (w) - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chd	ej.03cad	ej.ogd	sum
c03chd	Spirits; Denmark	0,414	1,110	0,738	-1,418	0,639	-0,332	0,000
c03cad	Spirits; cross-border shopping other countries	0,116	1,110	0,000	2,282	-3,061	-0,332	0,000
cogd	Other goods and services	99,470	0,999	0,250	-0,001	0,000	-0,998	0,000
	sum (weighted)	100	1,000		0,000	0,000	0,000	

Table 6. Price elasticities for Danmark - main groups

codes	Commodity groups	ej.03cd	ej.ogd	ej.sum
c03cd	Spirits	-0,77862	-0,33183	0,000
cogd	Other goods and services	-0,00118	-0,99822	0,000
	sum (weighted)	0,000	0,000	

4 Simulation results

Simulations show that the utility first increases monotonically with the tax on spirits, and then, after reaching a maximum, decreases monotonically with the tax rate. Table 7 and 8 show that there exists equilibria, and report the results for both types of games.

Three factors influence the magnitude of the equilibrium tax rates under utility maximization: i) own- and cross price elasticities associated with registered and cross-border purchased spirits, ii) the amount of cross-border shopping (both inward and outward), and iii) marginal external cost and the magnitude of the producer price. High amount of cross-border shopping /high own price- and cross price elasticity tends to pull the tax rate downwards. High marginal external cost per liter pure alcohol and low producer prices pull the tax rate upward.[19] We see that the ordering of the tax rate levels is the same for all equilibria, with Norway having the highest tax rate followed by Sweden and Denmark. This ordering is consistent with the ordering of the marginal external cost. The low tax rate in Denmark can also be explained by the significant amount of cross-border shopping, combined with the high own price- and cross- price elasticities. Sweden have a somewhat lower own price- and cross price elasticity, but a significant higher

[19] A low pre-tax price here implies a higher tax rate because the tax rate is measured as share of the pre-tax price.

cross-border shopping. Combined with a higher marginal cost and a lower pre-tax price, the result is a higher tax rate compared with Denmark. The Norwegian tax rate is highest, explained by several effects: High marginal external cost and low price elasticities combined with a smaller amount of cross-border shopping. Note that compared to the 2004 situation, the Norwegian tax rate is now higher than the Swedish tax rate.[20]

Compared to the situation in 2004, the equilibria imply a significant price decrease for all three countries. And, from Table 9 we see that compared to a situation where every country maximizes as if the economies are closed, the differences in tax rate and price are huge.[21] If ignoring the presence of cross-border shopping among the countries, the Norwegian price will roughly be around 80% higher, the Swedish around 86% higher and the Danish around 76% higher, compared to a situation where they take cross-border shopping into account. The loss in utility of ignoring the presence of cross-border shopping, correspond to about 1,5-2 billions Norwegian kroner for each country.

Note that the equilibrium prices in tables 7 and 8 imply that we will have substantial cross-border shopping between the countries. In fact compared to the situation in the base year 2004, the price differential, and thereby cross-border shopping, between Norway and Sweden is larger. Compared to the situation where the countries ignore the cross-border shopping when maximizing, the increase in price differential is even larger. On the other side, the price differential between Norway and Denmark will decrease.

Tables 7 and 8 show that we get higher tax rates and higher utility levels for each country in the sequential game. This means that in this case the simultaneous game equilibrium is Pareto- dominated by the sequential game equilibrium. Furthermore, the equilibrium tax rates change somewhat in the tables, although not much. This suggests that the maximizing tax rate in each country is rather insensitive with respect to the two other countries tax rate. Simulations of reaction curves confirms this.

We should be aware of that when speaking of the implications of cross-border shopping it consists of two components. Firstly, for a given vector of foreign prices, cross-border shopping will reduce tax rates compared to a closed economy. This is simply because of the fact that cross-border shopping involves real costs, and we are facing a trade-off. It is the non-competition component. Secondly comes the component of tax competition, i.e., strategic interaction. Consequently in our case, where it turns out that

[20] In 2004 the tax rate as share of pre-tax price is higher in Sweden because of a lower pre-tax price. Probably explained by the fact that Sweden have a state monopoly, as Norway, but a larger market, making it possible to import large quantas at significantly lower prices.

[21] Recall that with no cross-border shopping, the countries set their tax rate equal to marginal external costs.

the maximizing tax rates are nearly insensitive to changes in foreign tax rates and prices, it will mainly be the non-competition component that determines the tax rates in each country.

From Table 9 we see that in a closed economy the three countries will end up with different taxes and price levels. Especially Denmark will set a low tax. This suggests that some of the explanation of the large tax and price differences in the Scandinavian countries are the differences in estimates on the external effects of alcohol consumption, together with different pre-tax prices. The same structure will prevail if the countries take into account cross-border shopping. But, the introduction of cross-border shopping and its implications will alter the picture somewhat, making the price differential between Norway and Sweden somewhat larger, but lowering the price differentials between Sweden/Denmark and Norway/Denmark. On the other hand, it seems like taking cross-border shopping into account will lower the tax rates and price levels substantially for all countries.

For Norway and Denmark the actual tax rate are significantly lower than the closed economy tax rate, but for Sweden only slightly. In general, if we observe that each country's tax rate is fare away from the equilibrium tax rate, this could be interpreted as either one or more countries do not take into account cross-border shopping and tax competition according to our framework. Without further analyses, we cannot conclude that non of the countries take cross-border shopping and tax competition into account. This is due to the fact that if countries observe in the sequential game that a country has not played the equilibrium tax rate, then they will also want to deviate. Further, if a country in a simultaneous game is not fully aware of the implications of cross-border shopping, and the other countries are aware of this, then they will take this into account and not be playing the equilibrium tax rates. In our case we know that what we referred to as the tax competition component does not matter much, i.e., the maximizing tax rates are fairly robust to changes in other countries' tax rates. This means that if a country significantly deviate from playing the equilibrium tax rate, it does not take cross-border shopping into account according to our framework. Our results can then be interpreted as follows: All countries have started to take cross-border shopping into account when setting their tax rates, but for Sweden this is only to a very small extent. In this context it is interesting to note that both Norway and Denmark have had significant cuts in their tax rates the recent years, mainly justified by the large cross-border shopping. Sweden on the other hand, have not.

Table 7. Equilibrium tax rates, prices and utility level - simultaneous game

	Norway	Sweden	Denmark
Tax rate (t/q)	1,280	1,133	0,342
Price change (%) 1)	-28,8	-43,9	-22,8
Price level 2)	100,0	52,0	43,4
Utility level	452014,0	649226,4	558558,0

1) Price change compared to initial situation, i.e. situation in 2004.

2) Norwegian equilibrium price in the simultaneous game =100.

Table 8. Equilibrium tax rates, prices and utility level - sequential game

	Norway	Sweden	Denmark
Tax rate (t/q)	1,320	1,176	0,343
Price change (%) 1)	-27,6	-42,7	-22,7
Price level 2)	101,7	53,1	43,4
Utility level	452022,8	649227,1	558561,0

1) Price change compared to initial situation, i,e situation in 2004,

2) Norwegian equilibrium price in the simultaneous game =100.

Table 9. Utility maximizing values - closed economy 1)

	Norway	Sweden	Denmark
Tax rate (t/q)	3,137	2,999	1,380
Price change (%) 2)	29,1	5,2	36,9
Price level 3)	181,3	97,5	76,8
Utility level	450839,3	647136,8	557138,4

1) Countries maximize utility disregarding cross-border shopping, i.e., as if the economy was closed

2) Price change compared to initial situation, i.e. situation in 2004.

3) Norwegian equilibrium price in the simultaneous game =100

5 Conclusions

By constructing a simulation model we have analyzed commodity tax competition with respect to spirits in the Scandinavian countries. The results showed that equilibria exists, where the highest tax rate (measured as share of pre-tax price) and price prevails in Norway, then followed by Sweden and finally Denmark.

If the governments maximize utility as if cross-border shopping did not exist, this will lead to significantly higher tax rates on spirits compared to taking cross-border shopping and its implications into account. The tax and price structure across the Scandinavian countries can to a large part be explained by different estimates on social costs associated with alcohol consumption and pre-tax prices. Taking cross-border shopping into account will increase the price differential between Norway and Sweden compared to both the closed economy and the actual 2004 tax rates. This is interesting because it shows that if attention is given to cross-border shopping, this could mean that the price differentials increase between Scandinavian countries as well as decrease.

Furthermore, when comparing the actual tax rates with the equilibrium tax rates and the closed economy tax rates, we suggested an interpretation saying that Norway and Denmark to a larger extent than Sweden, have started to take cross-border shopping into account. Without further analyses this interpretation was possible because of the fact that the maximizing tax rates are rather insensitive with respect to the other countries' tax rates, i.e., the tax competition element is not of any large significance. As an consequence of this our results are rather robust with respect to what kind of game we assume. Nevertheless, in this model we get the result that the sequential game equilibrium gives higher tax rates and higher utility for every country, i.e., the sequential game equilibrium Pareto dominates the simultaneous game equilibrium.[22]

Finally, some of the limitations with the approach taken should be mentioned. First, close substitutes as wine and beer are a part of the aggregate good. Modelling these close substitutes could affect our results. Moreover, letting the tax rate on these also be endogenous could impact the maximizing tax rate of spirits. Second, our analysis does not take into account distributional and merit goods consideration, which are clearly relevant within a welfare optimal framework. Third, data on unregistered purchase is, by nature, associated with a high degree of uncertainty, which in turn could weaken the results. Fourth, in our analysis we find that the maximizing tax rates is fairly robust to changes in other countries' tax rates. This is due to the fact that the elasticities, which determines the maximizing tax rates, do not change much. Other ways of modelling could change the picture.

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[22] As demonstrated in appendix B, an alternative way of modelling transportation costs could alter this picture.

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A Tax revenue maximization

A.1 A necessary conditions for revenue maximizing tax rates

When we maximize the tax revenue associated with spirits, it can be shown that the first order condition can be written as

$$\frac{t^N}{p_R^N} = -\frac{1}{El_{p_R^N} S_R^N}. \tag{36}$$

Since $0 < t^N/p_R^N < 1$ we must have that $El_{p_R^N} S_R^N < -1$. In words: A necessary condition for the existence of a tax revenue maximizing tax rate on spirits is that the price elasticity of registered spirit purchase must take on values greater than one in absolute value, i.e. the demand must be sensitive enough. Likewise we have for Sweden

$$\frac{t^S}{p_R^S} = -\frac{1}{El_{p_R^S}\left(S_R^S + S_S^N\right)}. \tag{37}$$

And finally for Denmark

$$\frac{t^D}{p_R^D} = -\frac{1}{El_{p_R^D}\left(S_R^D + S_D^N + S_D^S\right)}. \tag{38}$$

The only difference from (36) being that we must include foreigners cross-border shopping in the formula for Sweden and Denmark, i.e., it is the change in total taxed demand which matters.

A.2 Governments' objective: tax revenue maximization

In this section we presents the results when the governments maximize tax revenue from spirits. For Norway we have

$$\max_{t^N} R^N(t^N, t^S, t^D) = t^N S_R^N, \tag{39}$$

where R^N is the tax revenue from spirits in Norway which in general depend on own and other countries' tax rates on spirits. Likewise, the Sweden maximizes tax revenue

$$\max_{t^S} R^S(t^N, t^S, t^D) = t^S \left(S_R^S + S_S^N \right). \tag{40}$$

Note that Norwegian (outward) cross-border shopping, i.e., spirits purchased in Sweden, is included in the Swedish revenue implying that Sweden gains tax revenue at the expense of Norway. Finally the objective of the Danish government is

$$\max_{t^S} R^D(t^N, t^S, t^D) = t^D \left(S_R^D + S_D^S + S_D^N \right) \tag{41}$$

Note that both Swedish and Norwegian cross-border shopping is included in the tax revenue for Denmark.

The first order condition associated with (34) can be written as

$$\frac{\partial R^N}{\partial t^N} = S_R^N + t^N \frac{\partial S_R^N}{\partial t^N} = 0. \tag{42}$$

Likewise the first order condition for (40) is

$$\frac{\partial R^S}{\partial t^S} = S_R^S + S_S^N + t^S \left(\frac{\partial S_R^S}{\partial t^S} + \frac{\partial S_S^N}{\partial t^S} \right) = 0. \tag{43}$$

And finally the first order condition for (41) is

$$\frac{\partial R^D}{\partial t^D} = S_R^D + S_D^N + S_D^S + t^D \left(\frac{\partial S_R^D}{\partial t^D} + \frac{\partial S_D^N}{\partial t^D} + \frac{\partial S_D^S}{\partial t^D} \right) = 0. \tag{44}$$

(42) – (43) implicitly define a reaction function for Norway, Sweden and Denmark respectively, i.e., the maximizing tax rate for a given country as a function of the other countries' tax rates. Let these functions be written as $t^N(t^S, t^D)$, $t^S(t^N, t^D)$ and $t^D(t^N, t^S)$. Two types of game are then considered, a simultaneous and a sequential game.

The equilibrium tax rates for a simultaneous game solves the following equation

$$\frac{\partial R^N}{\partial t^N} = \frac{\partial R^S}{\partial t^S} = \frac{\partial R^D}{\partial t^D} = 0, \tag{45}$$

i.e., the equilibrium is defined as the intersection of all the reaction functions.

For the sequential game we will assume that Denmark sets their tax rate first, then followed by Sweden and finally Norway. We use backward induction and start with Norway

$$\max_{t^N} R^N(t^N, t^S, t^D), \tag{46}$$

i.e., Norway maximizes the tax revenue taking the Swedish and Danish tax rate as given. The solution to this problem gives the reaction function for Norway, i.e., the maximizing Norwegian tax rate as a function of the Swedish and Danish tax rates, $t^N(t^S, t^D)$. Sweden maximizes tax revenue subject to the reaction function of Norway, taking the Danish tax rate as given, hence

$$\max_{t^S} R^S(t^N, t^S, t^D) \tag{47}$$

$$s.t.\ t^N(t^S, t^D).$$

The solution to this problem implicitly gives us the Swedish maximizing tax rate as a function of the Danish tax rate set in the first period of the game, i.e. $t^S\left(t^D\right)$. Denmark maximizes tax revenue subject to this and the reaction function for Norway:

$$\max_{t^D} R^D(t^N, t^S, t^D) \tag{48}$$

$$s.t.\ t^N\left(t^S, t^D\right) \text{ and } t^S(t^D)\ .$$

The maximizing Danish tax rate in equilibrium is given by the solution to this problem, and can be written as:

$$\frac{\partial R^D}{\partial t^D} + \left[\frac{\partial R^D}{\partial t^N}\left(\frac{\partial t^N}{\partial t^S}\frac{\partial t^S}{\partial t^D} + \frac{\partial t^N}{\partial t^D}\right) + \frac{\partial R^D}{\partial t^S}\frac{\partial t^S}{\partial t^D}\right] = 0. \tag{49}$$

A.3 Simulation results

The tax revenue from spirits first increases monotonically when tax rate on spirits increases, and then, after reaching a maximum point, decreases monotonically with the tax rate. This is in line with earlier findings. [23]

Tables A.3.1 and A.3.2 show that there exists an equilibrium under each type of game, and present the simulation results. Table A.3.1 gives us the results for the simultaneous game. In the first row we have the equilibrium tax rates for each country. We see that the equilibrium tax rates is highest in Norway, then followed by Sweden and Denmark. Compared to the situation

[23] In Aasness and Nygård (2009) we simulated Dupuit-curves (better known as Laffer-curves) for different cross-border exposed goods in Norway. For some goods this showed that at first the tax revenue increases monotonically with the tax rate, then, after reaching a maximum, decreases monotonically with the tax rate.

in 2004, this implies a price increase on spirits for all countries. The price increase is by far highest for Norway (30.1%) and Denmark (22.6%), followed by Sweden (2.2%). The ordering of the elasticities is consistent with the ordering of the own price elasticity of registered spirits in tables 1, 3 and 5. A country with a low price sensitivity with respect to registered spirits, gets the highest tax rate. Note that the equilibrium price differential between Norway and the two other countries is higher than in 2004. Especially the price differential between Norway and Sweden has increased substantially. On the other hand, the price differential between Sweden and Denmark is lower compared to the situation in 2004.

If we turn to the sequential game in Table A.3.2 we see that the sequential game consists of higher tax rates and higher tax revenue for all countries, compared to the simultaneous game. Note that the equilibrium tax rates change somewhat in the tables, although not much. This suggests that the maximizing tax rate in each country is rather insensitive with respect to the two other countries tax rate. This is confirmed by simulations of reaction curves.

Table A.3.1. Equilibrium tax rates, prices and tax revenue - simultaneous game, revenue maximization

	Norway	Sweden	Denmark
Tax rate (t/q)	3,169	2,879	1,131
Price change (%) 1)	30,1	2,1	22,6
Price level 2)	101,1	52,4	38,1
Tax revenue	3263,9	4692,7	1888,6

1) Price change compared to initial situation, i.e. situation in 2004.

2) Norwegian equilibrium price in simultaneous game for MITC with utility maximization =100.

Table A.3.2. Equilibrium tax rates, prices and tax revenue - sequential game, revenue maximization

	Norway	Sweden	Denmark
Tax rate (t/q)	3,172	2,902	1,140
Price change (%) 1)	30,2	2,7	23,1
Price level 2)	101,2	52,7	38,3
Tax revenue	3266,4	4694,7	1890,5

1) Price change compared to initial situation, i.e. situation in 2004.

2) Norwegian equilibrium price in simultaneous game for MITC with utility maximization =100.

B An alternative model with explicit transportation costs

B.1 Theoretical framework

Above we thought of the transportational costs as integrated in the utility function. For instance one liter of spirits purchased in Norway does not give the same utility for Norwegians as one liter purchased in Sweden. We can instead model this in a more explicit manner, i.e., we let spirits from different sources be perfect substitutes for each other while we introduce an explicit cost associated with transportation. For Sweden we then have

$$\max_{S_R^S, S_D^S, S_O^S, C^S} U(S_R^S + S_D^S + S_O^S, C^S) - \alpha_1 (S_R^S + S_D^S + S_O^S) \tag{50}$$

s.t.

$$\begin{array}{c} p_R^S S_R^S + p_D^S S_D^S + p_O^S S_O^S + p_C^S C^S = \\ I^S - g(S_D^S, S_O^S) + T^S \end{array} \tag{51}$$

$$S_R^S t_R^S + S_C^S t_C^S - T^S = R^S - R_{CB}^S. \tag{52}$$

where $g(S_D^S, S_O^S)$ is the transportation cost function. We have that $y^S = I^S - g(S_D^S, S_O^S)$, such that I^S is the full income without transportation costs. Transportation costs is then interpreted as including the costs of leisure. Substituting T^S in (51) gives

$$I^S - g(S_D^S, S_O^S) - \left(q_R^S S_R^S + p_D^S S_D^S + p_O^S S_O^S + q_C^S C^S\right) = R^S - R_{CB}^S. \tag{53}$$

We let the transportation cost function be quadratic

$$g(S_D^S, S_O^S) = \eta_1^{SD} S_D^S + \eta_1^{SO} S_O^S - \eta_2^{SD} \left(S_D^S\right)^2 - \eta_2^{SO} \left(S_O^S\right)^2. \tag{54}$$

Maximizing (50) subject to (53) gives the first order conditions

$$\begin{aligned} \frac{\partial U}{\partial C^S} &= -\lambda q_{C,}^S & (55)\\ \frac{\partial U}{\partial S_R^S} - \alpha_1 &= -\lambda q_R^S, & (56)\\ \frac{\partial U}{\partial S_j^S} - \alpha_1 &= -\lambda \left(p_j^S + \eta_1^{Sj} + 2\eta_2^{Sj} S_j^S\right) & (57)\\ \text{for } j &= D, O. \end{aligned}$$

Compared to the previous model the only difference is that in addition to the retail price comes the transportation costs, changing with the level of cross-border shopping. And spirits purchased at home is perfect substitutes for spirits purchased abroad, implying $\partial U/\partial S_R^S = \partial U/\partial S_J^S$ for all j. The Swedish demand for spirits in country j can be written as

$$S_j^S = \frac{p_R^S - \left(p_j^S + \eta_1^{Sj}\right)}{2\eta_2^{Sj}}. \tag{58}$$

Since Swedes are cross-border shopping in Denmark and 'other countries', we must have $p_R^S > p_j^{Sj} + \eta_1^{Sj}$ for $j = D, O$. To avoid a corner solution we must assume that the total price (marginal cost of purchasing) of cross-border shopped spirits increases with the amount of purchase abroad, i.e., $\eta_2^S > 0$.[24]

Since we cannot tax cross-border shopping, we will operate within the second best world.[25] We formulate the maximization problem as

$$\max_{p_R^N, T^N} V^S(\boldsymbol{p}^S, y^S + T^S) - \alpha^S \left[S_R^N + S_{CB}^S\right] \tag{59}$$

s.t.

$$S_R^S t_R^S + S_C^S t_C^S - T^S = R^S - R_{CB}^S, \tag{60}$$

where $S_{CB}^S = S_D^S + S_O^S$ (total outward cross border shopping) and $\boldsymbol{p}^S$ is a vector containing all prices. Maximizing and rearranging in addition to using Euler's theorem and the fact that the cost function is homogenous of degree one in prices and the cost parameters η_1^{Sj} and η_2^{Sj}, give us a formula that resembles (27)

$$\frac{t_R^S}{p_R^S} = \left[\frac{t_C^S}{p_C^S} - \frac{\alpha^S}{\lambda}\frac{1}{p_R^S}\right]\left[\frac{El_{p_R^S}\widehat{S}_R^S + \frac{S_{CB}^S}{S_R^S} El_{p_R^S}\widehat{S}_{CB}^S}{El_{p_R^N}\widehat{S}_R^S}\right] + \frac{\frac{\partial R_{CB}^S}{\partial t_R^S}}{\frac{\partial \widehat{S}_R^S}{\partial t_R^S} p_R^S}, \tag{61}$$

where

$$\frac{S_{CB}^S}{S_R^S} El_{p_R^S}\widehat{S}_{CB}^S = El_{p_R^S}\widehat{S}_D^S \frac{S_D^S}{S_R^S} + El_{p_R^S}\widehat{S}_O^S \frac{S_O^S}{S_R^S}. \tag{62}$$

The only difference from (27) is that the expression within brackets becomes identical.

We use this model to find equilibrium as described in the model with implicit transportational costs (MITC).

[24] It is not obvious what kind of sign the parameter η_2^{Nj} should have. If we think that the increased cross-border shopping is mainly caused by more and more people finding it profitable to go cross-border shopping or the same people crossing the border more frequently, η_2^{Nj} could be thought of as positive. On the other hand, if the increased cross-border shopping is mainly caused by the same people buying more spirits when they go abroad, η_2^N could be thought of as negative reflecting economies of scale in purchasing.

[25] In fact, to be in first best we must be able to tax total price, i.e., price including the transportational costs.

This model differ from the MITC in the way it models costs of purchasing through cross-border shopping. In the MITC the purchase of registered- and cross-border shopped spirits is included in the utility function as two different goods acting as substitutes for each other. They generate different utility because of some costs buried in the utility function. This model can be interpreted to focus on non-pecuniary costs, i.e., physical and psychological stress associated with cross-border shopping. This stress can reflect the fact that cross-border shopping involves long drives in combination with crowded department stores. Moreover, it seems natural that this non-pecuniary cost increases with both distance to the border and with the number of times a person is crossing the border. In the literature, this kind of costs have not got much attention. Nevertheless, it seems that these cost could be significant.

The model with explicit transportation costs (METC) can be interpreted to focus on pecuniary costs, such as gasoline expenditures and lost earnings (cost of leisure). The latter implies a flexible labour market. It is obvious that these costs are present, but not how significant they are compared to the non-pecuniary costs for the consumer decision.

Note some demand system properties that is implied by METC, a priori distinguishing it from MITC. In the alternative model outward cross-border shopping for country j depends only on the price of spirits (including transportational costs) in the country where the cross-border shopping takes place, and the price of registered spirits in country j (ck. equation (58)). This implies for instance that outward cross-border shopping for Norway in Sweden does not change when the Danish tax rate changes.[26] Furthermore, it implies that cross-border shopping is independent of income (Engel elasticities equal to zero with respect to cross-border shopping). All this is in contrast with MITC.

B.2 Specification of preferences

In METC the utility of the representative consumer for Norway, U^N, is specified as a LES, i.e.

$$U^N = B^N (S_R^N + S_S^N + S_D^N + S_O^N - \gamma_a^N)^{\beta_a^N} (c^N - \gamma_c^N)^{\beta_c^N}. \qquad (63)$$

with the same notation as above. This implies that the specification of preferences is identical to the top level of the model with implicit transportation costs. The only difference is that the decision on where to purchase spirits is determined solely of (58). We can illustrate the logic by considering an increase in tax rate on registered spirits. First the consumer will increase

[26]This is simply an implication of the fact that the marginal costs of purchasing spirits abroad in a given country do not change with the amount of cross-border shopping in other countries

cross-border shopping until marginal price of purchasing equals domestic price. Next he will consider changing total spirits consumption. In other words the decision problem can here be treated as a two stage decision problem. First determine how much cross-border shopping amount to, then determine the total demand for spirits and the aggregate good.[27]

B.3 Calibration procedure

Analogous to MITC it can be shown that we can identify a vector θ of unknown parameters from characteristics of the demand function at one point, i.e. it exists a function g

$$\theta = g(\mathbf{p},\ \mathbf{S},\ \mathbf{E}\ , C, Y, \sigma^T, \mathbf{d}, \boldsymbol{\eta}_2), \tag{64}$$

where the first six arguments are the same as with MITC, but instead of knowing a second substitution parameter we now need to know a vector of cost parameter,$\boldsymbol{\eta}_2$,and a vector of price differentials between home and abroad,$\mathbf{d}$.

Where METC asks for similar parameter input as the MITC, we use the same parameter values. This implies that σ^T for each country has the same value in METC as in MITC, and that the income elasticity is the same with respect to increase in registered spirit consumption. The cost parameters are set on the background of a sensitivity analyses with respect to the disaggregated own price elasticity they generates. Table B.3.1 - B.3.6 show the elasticity matrixes corresponding to table 1-6 for MITC.[28] From table B.3.1, B.3.3 and B.3.5 we see that the METC and the MITC generates approximately the same disaggregated own price elasticity for spirits in the base year. Furthermore the cross-price elasticities in the first column are approximately the same. Since we have a cost parameter associated with each country we could have let these differ from those in MITC, and still generating the same own price elasticity for spirits.[29]

Given all this, it should be apparent what differences that appears. Firstly we see that some of the cells have the value of zero, reflecting the fact that it is no substitution between going cross-border shopping in country A or country B. This is as mentioned an a priori property of this model.

[27] Implicitly we assume that the consumer always wants to purchase some spirits at home.

[28] Note that weighted row - and column sums do not always sum to zero. This is a consequense of the fact that the expenditure function is no longer homogenous of degree one in prices, but rather in prices and cost parameteres, the latter not included in the matrix. In addition also the fact that income is no longer treated as a exogenous variable, but instead varies with the cross-border shopping.

[29] One of these cross-price elasticities could be large in absolut value and another one small. It is the sum of substitution to cross-border shopping that matters for the magnitude of the disaggregated direct price elasticity for spirits.

Secondly the own price elasticity of cross-border shopping in country j with respect to the foreign price in country j, is far less in METC.

Table B.3.2, B.3.4 and B.3.6 differ from the corresponding tables for MITC because of two reasons. First, when changing the domestic and foreign prices we do not change the price of spirits from different sources by the same proportions. If this were the case we had to increase the cost parameters in addition. Secondly the Engel elasticity differ with respect to total spirit demand. This is a consequence of the fact that in METC the Engel elasticity with respect to cross-border shopping is zero a priori, as mentioned above.[30]

Note that it applies only locally that the two models generate approximately the same values for some price- and Engel elasticities. When moving far away from prices in 2004, i.e., doing a global analysis as here, these values may differ as well. In light of this it is specially interesting to check how sensitive the results are to how we model the behavior.

[30] Implicitly this means a different minimum consumption of total spirits.

Table B.3.1. Price elasticities, Engel elasticities (E), budgets shares (w), and tax rates (t/q) for Norway in METC - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chn	ej.03casn	ej.03cadn	ej.03can	ej.ogn	sum
c03chn	Spirits; Norway	0,603	1,572	2,204	-1,184	0,024	0,050	0,010	-0,627	-0,156
c03casn	Spirits; cross-border shopping Sweden	0,036	0,000	0,000	1,267	-0,215	0,000	0,000	0,000	1,051
c03cadn	Spirits; cross-border shopping Denmark	0,012	0,000	0,000	1,265	0,000	-0,835	0,000	0,000	0,430
c03can	Spirits; cross-border shopping other countries	0,066	0,000	0,000	1,274	0,000	0,000	-0,510	0,000	0,764
cogn	Other goods and services	99,282	0,998	0,240	0,000	0,000	0,000	0,000	-0,996	0,001
	sum (weighted)	100 %	1		0,000	0,001	0,000	0,000	0,000	

Table B.3.2. Price elasticities for Norway in METC - main groups

codes	Commodity groups	ej.03cn	ej.ogn	ej.sum
c03cn	Spirits	-0,794	-0,526	0,001
cogn	Other goods and services	-0,001	-0,996	0,001
	sum (weighted)	0,001	0,000	

Table B.3.3. Price elasticities, Engel elasticities (E) and budgets shares (w) for Sweden in METC - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chs	ej.03cads	ej.03cas	ej.ogs	sum
c03chs	Spirits; Sweden	0,536	1,41	2,799	-1,317	0,095	0,059	-0,561	-0,309
c03cads	Spirits; cross-border shopping Denmark	0,059	0,00	0,000	0,903	-0,235	0,000	0,000	0,668
c03cas	Spirits; cross-border shopping other countries	0,220	0,00	0,000	0,879	0,000	-0,536	0,000	0,343
cogs	Other goods and services	99,185	1,00	0,250	-0,001	-0,001	0,000	-0,997	0,002
	sum (weighted)	100 %	1,00		0,000	0,002	0,000	0,000	

Table B.3.4. Price elasticities for Sweden for METC- main groups

codes	Commodity groups	ej.03cs	ej.ogs	ej.sum
c03cs	Spirits	-0,560	-0,369	0,002
cogs	Other goods and services	-0,002	-0,997	0,002
	sum (weighted)	0,002	0,000	

Table B.3.5. Price elasticities, Engel elasticities (E) and budgets shares (w) for Denmark in METC - detailed groups

codes	Commodity groups	W(%)	E	t/q	ej.03chd	ej.03cad	ej.ogd	sum
c03chd	Spirits; Denmark	0,414	1,112	0,738	-1,412	0,227	-0,331	-0,404
c03cad	Spirits; cross-border shopping other countries	0,116	0,000	0,000	2,261	-0,814	0,000	1,447
cogd	Other goods and services	99,470	1,001	0,250	-0,001	0,000	-0,999	0,001
	sum (weighted)	100	1		0,000	0,001	0,000	

Table B.3.6. Price elasticities for Danmark in METC- main groups

codes	Commodity groups	ej.03cd	ej.ogd	ej.sum
c03cd	Spirits	-0,609	-0,259	0,001
cogd	Other goods and services	-0,001	-0,999	0,001
	sum (weighted)	0,001	0,000	

B.4 Simulation results

Simulations show that the utility first increases monotonically with tax on spirits, and after reaching a maximum, it decreases monotonically with the tax rate. The results are given in tables B.4.1 and B.4.2.

Overall the equilibrium tax rates are not very sensitive to wether we use the MITC or the METC. The largest difference is the Swedish tax rate, resulting in a price increase on about 4% when moving from MITC to METC. Nevertheless, the tax rates are somewhat higher in the METC for both equilibria.

We see that in the sequential game equilibrium the Danish tax rate is higher along with the Swedish, but the Norwegian tax rate is lower. Further, only Denmark gains from a sequential game compared to the simultaneous. [31]

It may seems strange that the MITC and METC give such similar results. We are far away from the initial prices, and would expect that the price elasticities evolves considerably different when prices change. In fact, simulations show that both the own- and cross price elasticities differ substantially when prices change. But, when considering for instance equation (27), we see that it is the relative relationship that matters. This relative relationship does not differ much between the two models.

Table B.4.1. Equilibrium tax rates, prices and utility - simultaneous game

	Norway	Sweden	Denmark
Tax rate (t/q)	1,350	1,2071	0,3482
Price change (%) 1)	-26,7	-41,9	-22,4
Price level 2)	103,0	53,8	43,6
Utility level	452275,6	649017,3	558486,8

1) Price change compared to initial situation, i.e. situation in 2004.

2) Norwegian equilibrium price in simultaneous game for MITC =100.

Table B.4.2. Equilibrium tax rates, prices and utility- sequential game

	Norway	Sweden	Denmark
Tax rate (t/q)	1,341	1,262	0,359
Price change (%) 1)	-26,9	-40,5	-21,8
Price level 2)	102,6	55,2	43,9
Utility level	452274,7	649013,6	558489,1

1) Price change compared to initial situation, i.e. situation in 2004.

2) Norwegian equilibrium price in simultaneous game for MITC =100.

[31] By doing additional simulations of reaction curves we observed that we not always have strategic complementarity in this case.