Bunker levy schemes and their impact on the competitiveness of short sea shipping

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Abstract

The need for reducing the greenhouse gas (GHG) emissions of the shipping industry is the main driver behind the adoption of Market Based Measures at the IMO. One of the measures currently debated and favored by most ship-owners is a bunker-levy scheme. This manuscript examines two different scheme types, a unit tax and an *ad valorem*, and their effect on the competitiveness of short sea shipping *vis-à-vis* other modes of transport and road in particular. As Short Sea Shipping is considered to be an environmental friendly alternative solution to road congestion, the quantification of possible adverse effects due to a MBM implementation is of great interest. A dynamic economic model, which takes into account the demand and supply interactions for maritime transport, is constructed so as to model possible modal shift for container freight. This new dynamic economic discrete choice model is applied in a hypothetical transportation scenario. Through the examination of differentiated tax and fuel price values, it is shown that for both bunker levy schemes a modal shift actually occurs. As far as the specific scenario is concerned, in the *ad valorem* case the modal shift amount depends heavily on the fuel prices as in the unit tax case it depends on the enforced tax values.

Key words: Market based measures (MBM), short sea shipping, modal shift.

1.Introduction

The necessity for additional regulatory actions is evident in the latest environmental study of the International Maritime Organisation (IMO) (2014) as shipping produced CO_2 emissions may increase up to 250% of the emissions of 2012 until 2050 (IMO, 2014). This necessity gains even more weight when taking into consideration the substantial drawbacks of the already implemented regulations. In the case of Emission Control Areas (ECAs) the possibility of an increase of the released CO2 volumes (Fagerholt et al., 2015; Doudnikoff and Lacoste, 2014; Gilbert, 2014) exists. As far as the Energy Environmental Design Index (EEDI) is concerned, it could have led to better results if it embraced also older vessels (Miola et al., 2011); characterized as an insufficient measure (Anderson and Bows, 2012). Last but not least, the suggestions provided by the

Ship Energy Efficiency Management Plan (SEEMP) are vague in terms of how shipping companies should apply those (Johnson et al., 2013).

The aforementioned facts prove indeed that in order to achieve environmental friendliness enhancement in the shipping industry and in general to tackle global climate change further actions are required. Towards this direction, the IMO has started a discussion about the possibility of market based measures (MBMs) implementation. Among the proposed MBMs is the enforcement of a bunker levy scheme; holding an eminent position in the agenda. Nonetheless, the multifold examination of every action prior of being taken is of vital importance, as the fear of adverse effects exists.

This research paper focuses on two different scheme´s forms, a unit tax and an *ad valorem*, and their effect on the competitiveness of short sea shipping (SSS) vis-à-vis other modes of transport; particularly road. Modal shift may actually occur (Psaraftis and Kontovas, 2010), which will hinder the exploitation of SSS; a transportation mode considered to be an environmental friendly alternative towards road congestion (European Commission, 2015). Specifically, the aim of the manuscript is twofold: a) the construction of a conceptual dynamic economic model with the inclusion of a levy parameter so as to estimate any possible modal shift that may occur regarding container transportation, b) the analysis of a hypothetical scenario so as to observe how the model functions and how a possible modal shift will vary dependent on the fuel prices and the alternative schemes.

As in principle MBMs aim, through the provision of economic incentives, at increasing operational efficiency, investing in green technologies and offsetting produced exhaust gases (IMO, 2016), those two different schemes´ forms are preferred due to their compliance with IMO´s principle of "polluter pays" i.e. the billed amount is directly imposed on the fuel costs; in the first case as a fixed amount and in the second as percentage varying dependent on the vulnerability of bunker prices.

The manuscript is formed as follows. Chapter 1 identifies the need for examining the impact of bunker levy schemes on SSS. Chapter 2 presents a literature review of the short sea shipping industry and market based measures. Moving on to chapter 3, it provides the theoretical framework of the model that is used for the analysis. Chapter 4 presents the results of different scenarios analyses and chapter 5 concludes the research paper; presenting the findings, limitations and recommendations for further studies.

2.Literature Review

2.1.Short Sea Shipping

The existing literature associated with SSS can be split into three categories. The first subgroup includes case studies and studies focusing on a regional level. Torbianelli (2000) for instance presents this transport mode in the Mediterranean Sea. Another case study, which deals with two Greek ports, regarding the competition of SSS and road transportation is found by Sambracos and Maniati (2012); providing suggestions for the promotion of the first i.e. improvements of port´s hinterland connectivity infrastructure and taking advantage of subsidiary programs regarding vessel investments. The case of the Baltic Region is addressed by Koi Yu Ng (2009), where an economic feasibility analysis is performed; showing that policy makers should focus on specific regions at which the exploitation of this mode may succeed and avoid generic solutions regarding the mode´s promotion. Lastly, the Yang et al. (2013) concentrates on a specific regional level in Taiwan and applying an AHP analysis identifies the influential factors correlated with the usage of SSS such as the port charging system, customs procedure, dedicated terminal etc.

The second subgroup of the literature is related to the competitiveness of SSS. Lombardo (2004) performed a cost benefit analysis compared to land based transportation. Additionally, Tostmann (2004) highlights the necessity for the construction of a business model that focuses on its promotion, while parallel satisfying the inflexible and just in time sensitive demand. Another noteworthy research performed by Johnson and Styhre (2015) presented the importance of reducing vessels´ port time in enhancing the energy efficiency of SSS; particularly even a small reduction of one hour would lead to an improvement of 2-8%. As far as the establishment of its position in multimodal transport chains is concerned, Paixa˜o Casaca and Marlow (2008) presented 13 logistics strategies e.g. “a total quality strategy”, “ an integrative strategy”, “ a freight-forwarding strategy” etc. that should be taken into consideration by SSS Operators.

Moving on to the third subgroup of literature, which consists of policy oriented studies, it is noteworthy to mention that at a European level the policies that were adapted for the promotion of this alternative transportation mode have not led to the intended results due to the vagueness and imprecision of the mode´s definition provided by the authorities (Douet and Cappuccilli, 2011). Staying at the European context and specifically focusing on the “establishment of the motorways of the sea” initiative, the role of ports is critical regarding its success and towards this direction Paixa˜o Casaca (2007) listed 21 pre requisites that ports should apply so as to exploit the possibility of becoming potential key notes within this initiative.

Based on the aforementioned literature, in generally, short sea shipping companies operate in a competitive environment under high pressure, as their costumers demand a high quality service level (Paixa˜o Casaca and Marlow, 2005). Taking also into account the recently introduced ECAs that lead to an operational fuel cost increase in addition to the high competition with road and rail so as to gain extra market share and establish their position in transport chains, it is evident that the introduction of a bunker levy scheme will lead to a growth of the operational expenses; hence putting even more pressure to the shipping companies. Hence, an examination of this MBM effect on the competiveness of SSS and modal shift is of high value and interest as the promotion and exploitation of this mode may be hindered.

2.2.Market based measures

Before moving on to the construction of our theoretical model it is imperative to mention the concept of market based measures as an economic incentive in the shipping industry. A proactive investigation of the potential resulting impacts of every environmental intending action is essential so as to prevent undesired effects i.e. world trade implications (Luo, 2013). Hence, it is coherent that the proposed MBMs by the member states, associate members and observer organisations to the Marine Environmental Protection Committee are examined thoroughly so that policy makers can choose an optimal solution that will contribute to the effort of tackling emissions.

The measures that have attracted the attention of researchers are: the inclusion of international shipping in an Emission Trading Scheme and the implementation of a bunker levy scheme. The first initiative works under the cap and trade principle and its emission reduction target should be definitively met due to its obligatory legal character (Psaraftis, 2012). Recent studies have concentrated on the implications of the two possible schemes that may be applied; an open ETS or a Maritime only ETS (METS). Both schemes will result in a workload and speed decrease (Wang et al., 2015). The bulk sector may experience a higher supply reduction compared to the liner sector in the case of an open scheme (Luo, 2013). Furthermore, an aspect that favors the implementation of a METS is the low administrative required effort by the shipping companies (Koesler et al., 2015).

Moving on to the MBM of a bunker levy scheme, researchers support its enforcement opposite to the negativity that is expressed by stakeholders (Giziakis and Christodoulou, 2012), as it is argued that its effectiveness is based on the fact that shipowners will have the possibility of acting proactive towards environmental friendly technological investments as the extra resulting costs will be priory known (Psaraftis, 2012). However, stakeholders are not in favor of its possible enforcement, as it is believed that the costs will be passed along the supply chain; hence, resulting to its inadequacy (Global Shippers´ Forum, 2012). Aside from this conflict that needs to be addressed, the study of Lee et al. (2013)

presented that liner shipping competition will increase in long haul distances as also demand for shipping services in short distance routes. The aforementioned studies consist, at least in our knowledge, the existing literature regarding MBMs in the maritime industry. The next section has as its main core the construction of the economic model that will be used for the analysis based on Kosmas and Acciaro (2015).

3.A dynamic economic discrete choice model

Discrete choice models have been explored from multifaceted aspects. The basic distinction among them depends on the data used for the studies; aggregate and disaggregate. The latter refers to data that include total freight volume flows by each mode in a regional or national context, whilst the latter consists of data of discrete consignments (Zlatoper and Austrian, 1989). An additional distinction of the existing models that can be taken is whether they are econometric or not.

A behavioural econometric freight modeling technique is the discrete choice analysis[1], which will constitute a part of the basis of the paper´s model construction. Under a discrete choice model framework, the individual (in our case the shipper or cargo owner) selects the appropriate for his or her mode according to its achieved utility level (Ben-Akiva and Lerman 1985). The determinant factors for the utility estimation vary as has been shown in many studies e.g. cost, transit time and shipments´ frequency (García-Menénez et al., 2004), cost, freight rates and origin and destination (Cascetta, 2001; Domencich and McFadden, 1975).

The conceptual binary logit model constructed for the examination of the bunker levy schemes, including only road and short sea shipping, is formulated as follows:

$P_{ij} = f\ (U_{ji})$ (1)

where $U_{ji} = V_{ji} + \varepsilon_{ji}$ (2)

j are the two alternative transport modes (*j*= *r* or *s*, *r*= road and *s*=sss),
i= shipper-carrier,
U_{ji} stands for the net utility function
P_{ij}=the probability that *i* chooses *j*
e_{ji}= error term of the utility
Vji= the utility´s portion of *j* that is observed by *i*

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[1] In general, models that focus on the decisions among the different choices that consumers face are defined as behavioural. Discrete choice models are the behavior models that represent the transport decisions among a discrete set of alternative modes.

Equation (1) can be further expanded as

$$P_j = \exp(V_j) \Big/ \sum_{j=r,s} \exp(V_j) = 1/(1 + \exp(V_r - V_s))$$

And $\sum_{j=r,s} P_j = 1$

Since the model will not take into account the decision-making differences of shippers, it is attainable to drop *i* in the equations. By dropping *i,* it is assumed also that “past experience” does not play a role in the decision making process;

$$U_j = \theta_{j1}x_{j1} + \theta_{j2}x_{j2} + .. + \theta_{jz}x_{jz} + \varepsilon \quad (3)$$

The error term is also dropped from the equation as we will focus only on the observed utility.Thus for every mode the utility is stated as follows

$$U_r = \theta_{r1}x_{r1} + \theta_{r2}x_{r2} + .. + \theta_{rz}x_{rz}$$
$$U_s = \theta_{s1}x_{s1} + \theta_{s2}x_{s2} + .. + \theta_{sz}x_{sz}$$

The aforementioned attributes, assumed to have a linear relationship, of each transportation mode are stated as $x_{j1},\ldots,x_{jz}$ and $\theta_1,\ldots,\theta_z$ are z number of coefficients. At this stage of the paper, the factors that are chosen to be included in the model are cargo volumes, speed and transportation costs (freight rates).

$$U_r = V_r = \theta_{r1}x_{r1} + \theta_{r2}x_{r2} + \theta_{r3}x_{r3} \quad (4)$$

$$U_s = V_s = \theta_{s1}x_{s1} + \theta_{s2}x_{s2} + \theta_{s3}x_{s3} \quad (5)$$

where x_{j1} = cargo volumes= demand for every transport mode assumed as exogenous,
x_{j2}= speed taken as exogenous,
x_{j3}= freight prices as endogenous variable.

In order to estimate freight rates, it is important to introduce at this point an economic equilibrium model that takes into account the interactions of supply and demand; including also at the same time a tax parameter. The existing literature of market equilibrium in the shipping industry e.g. Beenstock and Vergottis (1993), Lewis and Koopmans(1939), Strandeness (1984) and market interactions e.g. Haralambides et al. (2004) examine the new building and second-hand markets behaviour; Alizadeh and Talley (2010) focus on the microeconomic determinants of freight rates, is extensive and provides the theoretical background for the construction of the equilibrium model, which will have as basis the cobweb theorem of Kaldor (1934).

According to Kaldor (1934) a greater supply Q1 intersects the demand curve at price P1 in the first period of the cobweb model. Due to the high supply value and low price, in the second period a lower supply Q2 is presented intersecting the demand curve at a higher price value P2. This increased price will subsequently increase the supply in the next stage at Q3, which will decrease the new price value at P3. This process continues for the next periods of the model as presented in figure1. Nevertheless, it is noteworthy to mention that since the price sensitivity of demand and supply is the underlying factor of the model´s behaviour, when distortions appear, then the market enters into a new cobweb model.

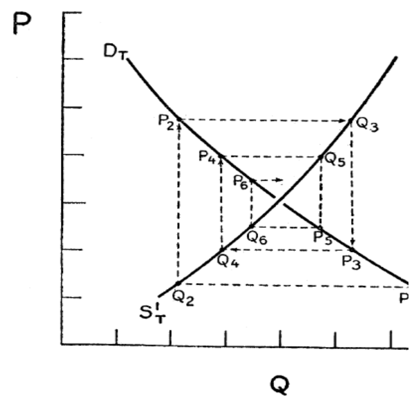


Figure1: Cobweb model; Source: Ezekiel (1938)

Demand in the present study is taken as exogenous following Luo et al. (2009) and Taylor (1976). The new building market is not included in the model since it does not influence freight rates. Likewise, the sale and purchase market is excluded, as it does not have an impact in the industry´s supply. Nonetheless, the lead time of new order delivery, which is stated as θ, plays an important role as new capacity is introduced into the sector. In the present model it is assumed that the freight rate function depends on fleet capacity Z (in TEU), delivery of new orders N (in TEU), profit Π (in \$), demand X (in TEU) and for this study also tax amount (T). Hence: Freight Rate = f (Z, N, Profit, T, X).

According to Luo et al. (2009) new orders for period t are expressed as

$N_{t=}\, n \times \Pi_t$ (6)

where n is the average proportion of the profit invested in the purchase of new vessels.

Profit as is expressed in the following equation (7) is assumed to depend on freight rates P (\$/TEU), demand X (TEU) and vessel´s costs TC. The model does not include all costs; only fuel costs, as these represent the highest percentage of voyage costs (Psaraftis and Kontovas, 2013) and operational costs are mainly fixed costs.

$\Pi_t = P_t X_t - TC_t$ (7)

$TC_t = F_t * \Psi_t$ (8)

where, following Wang et al. (2015)

$F_t = \rho_t f_t \lambda_t S_t^3$ (9)

ρ is operating time at sea (in hours), f represents the fuel price ($/ton) and since capacity and freight rates do not affect its value it is taken as exogenous, λ is the energy efficiency´s coefficient of a ship and S (knots) stands for average speed

and

$$\Psi_t = \frac{X_t * d_t}{H_t * S_t * \rho_t} \quad (10)$$

referring to the required number of ships for satisfying demand; d stands for the route distance (nautical miles) and H for the average capacity (TEU) of the vessel.

The change in fleet capacity is presented as:

$$\Delta Z_t = Z_t - Z_{t-1} = N_{t-\theta} \quad (11)$$

and by combining the above equations a new dynamic one arises:

$$\Delta Z_t = n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} - F_{t-\theta})\Psi_{t-\theta}) \quad (12)$$

Following the study of Luo et al. (2009), applying the cobweb theorem, the freight rate change is obtained from the equation:

$$\Delta P_t = \delta * (\Delta X_t - \varphi * \Delta Z_t) \quad (13)$$

where, $\Delta P_t = P_t - P_{t-1}$, δ>0 represents the freight adjustment factor based on demand and supply alterations and φ>0 (constant) is the average slot capacity utilization rate.

In the case of a tax scheme enforcement then the equations change accordingly as follows:

For the unit tax scenario

$$\Delta P_t = \delta(\Delta X_t - \varphi \Delta Z_t) = \delta \Delta X_t - \delta \varphi n(P_{t-\theta} X_{t-\theta} - \rho_{t-\theta}(f_{t-\theta} + TP)\lambda S_{t-\theta}^3 \Psi_{t-\theta}) \quad (14)$$

And for the ad valorem scenario:

$\Delta P_t = \delta(\Delta X_t - \varphi\Delta Z_t) = \delta\Delta X_t - \delta\varphi n(P_{t-\theta}X_{t-\theta} - \rho_{t-\theta}f_{t-\theta}(1+VP)\lambda S^3_{t-\theta}\Psi_{t-\theta})$ (15)

At this point by taking equations (14) and (15) for each different taxation scheme and applying them in equations (4) and (5), the new utilities (taking into consideration the levy values) of the two examined transportations modes can be calculated as follows:

For the unit tax scenario:

$$U_r = V_r = \theta_{r1}x_{r1} + \theta_{r2}x_{r2} + \theta_{r3}x_{r3}$$

$$Us=\theta_{s1}x_{s1}+\theta_{s2}x_{r2}+\theta_{s3} (\delta(\Delta X_t - \varphi\Delta Z_t)=\delta\Delta X_t - \delta\varphi n(P_{t-\theta}X_{t-\theta} - \rho_{t-\theta}(f_{t-\theta}+T)\lambda S^3_{t-\theta}\Psi_{t-\theta})+P_{t-1})$$

For the *ad valorem* :

$$U_r = V_r = \theta_{r1}x_{r1} + \theta_{r2}x_{r2} + \theta_{r3}x_{r3}$$

$$Us=\theta_{s1}x_{s1}+\theta_{s2}x_{r2}+\theta_{s3}(\delta(\Delta X_t - \varphi\Delta Z_t) = \delta\Delta X_t - \delta\varphi n(P_{t-\theta}X_{t-\theta} - \rho_{t-\theta}(f_{t-\theta}+(1+T)\lambda S^3_{t-\theta}\Psi_{t-\theta})+P_{t-1})$$

By identifying the new dynamic utility equations it is feasible to estimate with the same token also the new probabilities values; hence acquiring information of a possible modal shift after a tax scheme enforcement. The following section of the present research paper presents a hypothetical scenario of the competition between short sea shipping and road container transportation after the alternative levy schemes implementation.

4.Analysis and Results

In order to identify the impact of a levy enforcement the first step is to calculate the first order conditions of the mode´s utility. For both cases it is proved that:

$$\frac{dU_s}{dT} < o$$

The result shows that the utility of SSS will decrease after a tax implementation; thus a modal shift is expected. Moving on, a hypothetical scenario is developed so as to present how the developed dynamic model works and examine the impact of the two examined schemes under alternative tax and fuel price values. However, before the analysis it is important to mention some further assumptions i.e. demand, speed and freight rates for road transport are taken as exogenous, speed for SSS also as exogenous and the modes are available at all times. Next, the values of the variables and parameters used in the analysed scenario are illustrated as follows:

Xs_{t-1}	**1950000 TEU**
d	750 nm
S	12 knots
H	2000 TEU
Fuel price ($/t)	300 or 600
θ_{s1}	0.000003
θ_{s2}	0.0055
P_{t-1}	800 $/TEU
λ	0.0012
θ_{s3}	-0.003
δ	0.00894
n	0.0000034
φ	42.27
θ_{r1}	0.000001
θ_{r2}	0.0045
θ_{r3}	-0.002
X_r	1500000 TEU
S_r	43 miles/hour
X_{r3}	1330 $
X_{st}	2200000 TEU
$P_{t-\theta}$	900 $/TEU
$X_{t-\theta}$	1850000 TEU

It is important to mention that the values of λ, φ, δ and n were taken from Luo et al. (2009). By applying different price values for the alternative tax schemes as also for alternative fuel scenarios the first results of the analysis regarding modal shift from SSS to road are presented as follows:

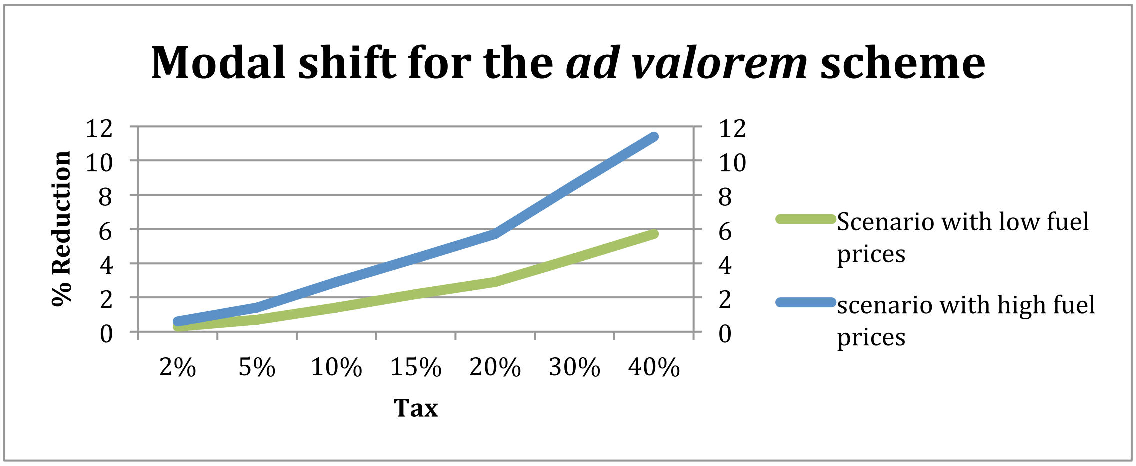
For the *ad valorem* scheme:

Tax percentage (%)	Modal shift percentage (%)	
	Low fuel prices (300$/t)	**High fuel prices (300$/t)**
2	0.3	0.6
5	0.7	1.4
10	1.4	2.9
15	2.2	4.3
20	2.9	5.7
30	4.3	8.6
40	5.7	11.4

Source: own calculations

It is evident that modal shift actually occurs after the implementation of the scheme. The above table is a good representation of the possible results as it applies differentiated tax percentage values in different fuel price scenarios. It is

shown that fuel costs play a dominant role in the final outcome. Besides the fact that when the levy percentage value increases the modal shift from SSS to road increases for both fuel price cases, when the bunker costs are high then the occurred modal shift rises much more in comparison to the situation when bunker prices have a lower value.
This is also illustrated in the following graph:

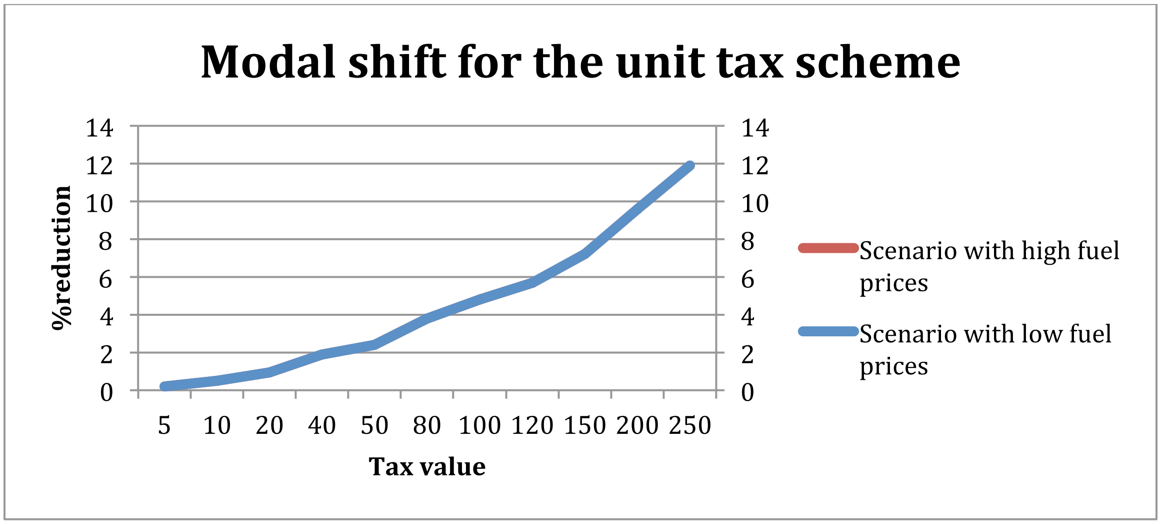


For the Unit tax scheme:

Tax amount ($/t)	Modal shift	
	Low fuel prices (300$/t)	**High fuel prices (300$/t)**
5	0.2	0.2
10	0.5	0.5
20	0.95	0.95
40	1.9	1.9
50	2.4	2.4
80	3.8	3.8
100	4.8	4.8
120	5.7	5.7
150	7.2	7.2
200	9.6	9.6
250	11.9	11.9

Source: own calculations

As far as the unit tax scenario is concerned, as above, a modal shift is expected. With the same token different fixed tax values are examined under different bunker costs. The outcome shows indeed that modal shift will occur. Nonetheless, for the present examined hypothetical scenario, an interesting fact is shown, that the results remain the same for both low and high fuel costs. It would be naïve to conclude that the fuel price does not play any role in the final outcome. Further research will be conduct for this case. The above table is illustrated in the following graph.



5.Conclusion

The present working paper is the first attempt to assess the impact of bunker levy scheme enforcement in the competitiveness of short sea shipping *vis-à-vis* road transportation; particularly focusing on container transportation. A dynamic economic model is constructed so as to estimate a possible modal shift occurrence. Taking as basis the discrete choice theory and the cobweb theorem the new dynamic model that takes into account the supply and demand interactions in the SSS industry is then applied in a scenario under differentiated schemes and alternative fuel and tax values.

A modal shift actually occurs from sea to road for both bunker levy schemes. Specifically, for the examined scenario it is shown that in the case of an *ad valorem* scheme the percentage of modal shift depends on the volatility of bunker prices. Specifically, in the case of high fuel price values then a higher modal shift takes place compared to the situation of low fuel prices. As far as the unit tax scheme is concerned, the outcome depends only on the applied tax values.

Since this is the first draft of this research, the results can not be generalized and further examination is required. Firstly, further investigation regarding the sensitivity of the parameters and variables applied in the model is required so as to assess their impact in the final results. Afterwards, different scenarios should be also examined and specifically since SSS demand is price sensitive it should be looked at from a regional perspective for additional results. Nevertheless and despite the study´s limitations at this point, it is the first attempt to address the impact of MBM on SSS by providing a new conceptual framework for assessing modal shift.

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