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BUNKER LEVY SCHEMES FOR GHG EMISSION REDUCTION IN INTERNATIONAL SHIPPING

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ABSTRACT

Market based measures (MBMs) are currently under consideration in the IMO as an emission mitigation strategy for maritime transport. The measure, which will be analysed in this paper and has attracted significant attention, is the enforcement of a bunker levy scheme. The following research paper focuses on the economic implications of the introduction of two different forms of a tax-levy scheme in the bulk shipping industry. The first scheme is in the form of a specific unit tax per ton of fuel and the other in the form of an ad valorem tax, enforced as a percentage of fuel prices. An economic model based on the cobweb theorem is constructed for the aforementioned schemes. A speed and fuel consumption reduction or an improvement in the sectors energy efficiency would be expected for ship-owners and operators to cope with higher costs. The resulting speed reduction depends in the first scheme on fuel prices and the amount of the tax, whereas in the second scheme the reduction depends only on the imposed percentage. As both levy schemes lead to a profit decline, the extra resulting costs will be allocated in the industry based on its market situation. It is revealed that when the market situation is prosperous, with high freight rates and without suffering from overcapacity, the extra costs can be transferred from ship-owners to shippers easier than in a situation when the industry is in a trough or recession.

Key words: Market based measures (MBM), green shipping, Greenhouse Gas emissions, international tax.

1. INTRODUCTION

The third IMO environmental study officially justified what was already suspected; the necessity for further emission abatement measures as exhaust gas produced by maritime transport still keep increasing rapidly (IMO, 2014). The IMO, the responsible agency for international shipping´s environmental performance character, has just only recently introduced emission abatement regulations i.e. the enforcement of Emission Control Areas (ECAs), the Energy Environmental Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), mainly due to shipping´s international character.

Nevertheless, the above initiatives proved to have significant drawbacks. ECAs despite tackling NOx and SOx may boost the produced amount of CO2 (Fagerholt et al., 2015; Doudnikoff and Lacoste, 2014; Gilbert, 2014). The EEDI, being not sufficient enough to condense the production rate of shipping emissions (Anderson and Bows, 2012), could have led in a higher environmental effectiveness only if it embraced also older ships (Miola et al., 2011). As far as the SEEMP is concerned, crucial gaps have been identified in its system compared to other best practice enablers (ISO 50001 and ISM), which therefore may not contribute in the enhancement of shipping companies´ energy management system (Johnson et al., 2013).

Due to the aforementioned factors, the implementation of market-based measures (MBMs) as a potential GHG emissions mitigation solution is being considered. One of the examined measures that has attracted the attention of researchers and constitutes the present paper is the enforcement of a levy scheme as a “way” to increase operational efficacy. It is vital that every abatement action taken should be examined thoroughly prior its final implementation in order to avoid adverse effects in the shipping industry. Implications on world trade, global production of goods (Luo, 2013), modal shift occurrence (Psaraftis and Kontovas, 2010) and other environmental side effects as were mentioned previously associated with the ECAs can serve as a perfect example. Thus, an in-depth and manifold examination of this potential MBM is imperative. IMO supports the

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principle of “polluter pays”. Accordingly, it is understandable that ship-owners should provide an environmental compensation for their operations.

In this research paper, an investigation and benchmark of two different bunker-levy schemes in the international bulk-shipping sector are presented. The first scheme is in the form of a specific unit tax per ton of fuel and the other in the form of an ad valorem tax, enforced as a percentage of fuel prices. The tax incidence and economic implications that arise from those levies enforcement on the bulk shipping industry are analysed and quantified. A dynamic equilibrium model is constructed so as to address the true impact of the levy schemes.

As the levy scheme is thought to be a market-based measure that may provide the required incentives to ship-owners for enhancing energy efficiency in their operations, it is essential to quantify the effects in the shipping industry in terms of profit and operational behavior at least for the short term and to provide also ways for cost minimization. Furthermore, this study will provide a framework describing the levy costs allocation in the sector. The examination of who actually and to what percentage will born the extra costs is important, since there is the belief that these costs will be just passed from the ship-owners along the supply chain (Global Shippers’ Forum, 2012); hence being inadequate to put pressure to carriers to improve their operational efficacy.

This study adds value and contributes to the academic community, policy makers and industry practitioners. Despite the multifold existing economic and econometric models that reflect the markets consisting the maritime industry, no model exists with the inclusion of a levy scheme addressing issues related to the market equilibrium. Secondly our paper will act as framework to policy makers for understanding the effects of proposed policies on the industry´s involved stakeholders. As far as the contribution to practitioners is concerned, since the economic implications are quantified, our analysis can act as a tool for operational and competition strategies improvement.

2. MARKET BASED MEASURES (MBMS)

The international character of maritime transport is the basic obstacle of immediate regulation enforcement. Nevertheless, emission abatement policies for other transportation modes are observed in a country based framework through different implementation forms. Environmental taxes are observed, indeed resulting in exhaust gases mitigation, in the car sector (Rogan et al., 2011; Hennessy and Tol, 2011) and in the aviation industry (Swedavia AB, 2015; (Flughafen Zürich AG, 2010).

Among the final by the Member States, Associate Members and observer organisations proposed measures-schemes the two currently under examination are the Emission Trading Scheme (ETS) and the bunker levy enforcement. Generally, an ETS should definitely satisfy the CO2 reduction cap that has been set, unless otherwise it would be illegal for ships to trade (Psaraftis, 2012). Nevertheless, a debate exists regarding the “formula” of this scheme; an open ETS or a maritime only ETS. Wang et al. (2015) identified in both cases a speed, workload and fuel consumption decrease. Respectively, the inclusion of the shipping industry in an open ETS bears a threat for global trade, as it may lead to inconsistencies in terms of international production of goods (Luo, 2013) and a METS is able to operate as an effective measure only if taking into consideration the various characteristics of the international shipping business (Koesler et al., 2015).

As far as the establishment of an International Greenhouse Gas Contribution Fund is concerned, it enforces a levy on all ships over 400GT for every fuel type. It is noteworthy to state that in the proposal the term “contribution” is used referring to the payable amount by not using the terms tax or levy, as IMO is not a tax-raising agency. Nevertheless, in reality this “contribution” can still be considered as a levy-tax. The concept of a levy-scheme has attracted the attention of researchers lately. It is argued to be the most effective MBM as the extra resulting costs will be prior known enabling so ship-owners to act proactively, investing in new technologies (Psaraftis, 2012). Additionally, Kapetanis et al. (2014) claim that it is the most suitable and easiest to be enforced MBM, but highlight that flexibility regarding the payable amount is needed, which should be dependent on the market situation, as the fear of severe distortions even in sustainability issues caused from a possible modal shift towards less environmental friendly transportation modes exists. The study of Lee et al. (2013) explored the world wide economic impact in terms of profit, implications on GDP and competitiveness

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resulting from a levy enforcement in container shipping. Sever competition among liner companies in long haul routes, attraction of more demand in short distance routes and 0.02% loss in China´s GDP are their major findings. Lastly, they proposed that a levy scheme should be differentiated according to the shipping costs of every trade route.

Moving on with the comparison of the levy scheme´s environmental effectiveness and other abatement regulations, Cariou and Cheaitau (2012) argued that in terms of resource allocations the former is the preferable option compared to the proposed European only speed limit measure. In comparison to an ETS in terms of mitigation effectiveness, according to the report of the Congressional Budget Office (2008), a levy scheme can result at the same emission reduction levels at half the price of the ETS. Despite the fact that researchers are in favor of a levy-scheme as was previously described, stakeholders seem to be negative towards its enforcement (Giziakis and Christodoulou, 2012). It is argued that the extra costs will just be passed along the supply chain, resulting to the scheme´s ineffectiveness in terms of environmental efficacy enhancement (Global Shippers' Forum, 2012). Thus, it is essential to examine the multifold aspects of a levy scheme, examining its economic implications.

3. METHODOLOGY

3.1. TAX INCIDENCE AND COST PASS-THROUGH THEORY

Literature on tax incidence focuses on how tax policies affect the distribution of economic welfare, as economy´s equilibrium changes with tax enforcement (Kotlikoff and Summers, 1987). As the extra costs applied are not usually borne by those that are legally obliged to pay, but are commonly passed along the supply chain, tax incidence has attracted considerable attention and has been applied in different industries. Examples can be found in: Tockarick (2006) who provides an example of estimating the welfare implications of a tariff enforcement in international trade, using a general two-country equilibrium model with constant elasticities; Bonnet and Réquillart (2013) where the authors used a general random coefficient logit demand model to examine the impact of an ad valorem and excise tax in the soft drink market of France; Agostini and Jiménez (2015) that applied the Suits Index (a suitable method for the measurement of progressivity of a tax) to estimate the distributional incidence of the gasoline tax in Chile; Marion and Muehlegger (2011), where the authors applying also a supply and demand model, an investigation of the state´s gasoline and diesel tax pass through rate to retail prices was presented.

Cost pass-through refers to the price change of a product offered in a business industry resulting from its cost change. A thorough description of this theory framework is analytically presented in the report of RBB Economics (2014) prepared for UK´s Office of Fair Trading. The analytical report describes the cost pass through theory´s characteristics in situations of an industry wide or idiosyncratic cost change, or when differentiated supply and demand conditions are applied and in cases when the business environment is characterised by a diverse degree of competition. In economics, tax incidence and cost pass-through are closely linked through the supply and demand equilibrium concepts and aim at identifying in the case of a tax change how the levy will be allocated between consumers and producers. Briefly, literature examples of the theory´s implementation are found for gasoline taxes in Doyle and Samphantharak (2006), for tobacco taxation in Hanson and Sullivan (2009) and Harding et al. (2012) and for sales taxation in Besley and Rosen (1999).

3.2. EQUILIBRIUM MODEL IN THE BULK SECTOR

The main purpose of the paper is not to construct another equilibrium model of the shipping industry for forecasting reasons or to identify any other relationship among its interacting factors, but to examine the implications of the proposed levy schemes. As a fair amount of shipping market equilibrium studies have already been carried out in maritime economics e.g. Tinbergen (1959), Beenstock and Vergottis (1993), Lewis and Koopmans(1939), Strandeness (1984), the necessary background for constructing our economic model so as to proceed with our core analysis, exists.

According to Tsolakis (2005), some models from the aforementioned literature, besides from having a theoretical basis and a close context, are considered to have significant drawbacks linked with their CLRM

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assumptions (heteroscedasticity, autocorrelation and multicollinearity). Nonetheless, this is not of our concern as only the functional related framework of the international shipping industry is of our interest in order to establish our economic model. Additional literature reviews that are valuable for understanding the maritime industry can be found in: Haralambides et al. (2004), where a model of the new building and second-hand markets behavior is provided; Alizadeh and Talley (2010), where the authors present, the microeconomic determinants of freight rates and contract times of the bulk shipping sector with the use of a simultaneous equations method.

A recent study of Luo et al. (2009) presents an econometric model for the analysis of freight rates in the container market using as a basis the interactions of the market´s demand and fleet capacity. The authors apply the three-stage least square method for the quantification analysis, with the model showing a high explanatory power of 90%. This study is of great interest to us, since the cobweb theorem is applied for the design of a maritime equilibrium model. To our knowledge, it is the most recent study that applies this theorem as the basis for interpreting and reflecting the shipping industry´s supply and demand interacting factors.

The theorem explains price and supply and demand fluctuations in an industry, where the time factor plays an important role. In order to be applied, three prerequisite conditions need to be satisfied, according to Ezekiel (1938). The first condition is that production is completely set based on the producers´ response to prices under the situation of perfect competition and also that actions taken by the producer individually will not affect the market. The second condition refers to the fact that the price is determined by the available supply. Last, in order the production to be changed, a full period is required as lead-time.

Despite the fact that the study of Luo et al. (2009) has a high explanatory power and adds value to the industry and academia, we are skeptic towards their application of the cobweb theorem to the liner industry as there is still debate regarding the industry´s characteristics so as to fulfil the above prerequisites. The first issue is associated with the form of competition inside the liner shipping business´s environment as it has been argued to be an oligopoly (Sys, 2009; Munari, 2012; OECD, 2015). Another important dispute is the accusation that shipping companies may affect and fix prices. Specifically, the liner transport industry has been criticized for alleged conferences, alliances and agreements, which resulted in the need of regulations during the last years. However, this situation has not disappeared if we take into consideration that the potential “P3” alliance was withdrawn at the last minute. Nevertheless, the theorem can be applied to the bulk sector, since no conflict is identified in terms of the prerequisites fulfillment. This open industry works under full competition for which the behaviour of freight rates and supply is well known and can be found in the section´s first mentioned models. Furthermore, an individual shipping company cannot influence the markets behaviour. Additionally and in line with the importance of the time factor in the cobweb theorem, a radical supply adjustment cannot take place instantaneously but requires a significant lead-time.

The cobweb model, according to Kaldor (1934) works as following: At the first phase a greater supply Q1 is presented intersecting the demand curve at its responding price P1. At the second phase a reduced supply Q2 is identified due to the previous observed price value, that consequently intersects the demand curve at a higher value P2. The higher price will lead to an increase in the supply at Q3 that will then intersect the demand curve at a lower price value at P3. This decreased price will result in a decrease in the supply value in the next phase, Q4, which will then drive the price up at P4. The same procedure will continue for the next phases. The price sensitivity of supply and demand is the determining factor for the behaviour of the industry´s models. When distortions in supply and demand appear, the industry will probably enter in a new cobweb model; however, this case is out of the scope of this paper.

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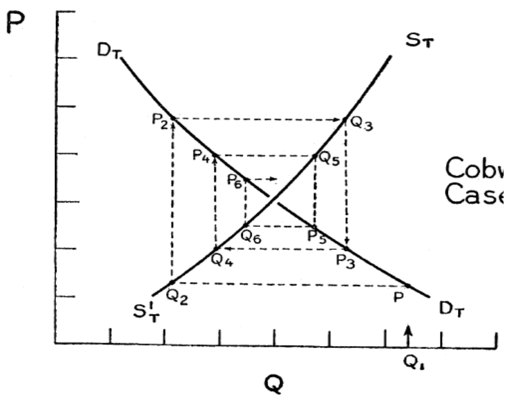

Figure 1: Cobweb model; Source: Ezekiel (1938)

Despite the above-mentioned studies there is no model that includes a clear tax-levy parameter. It can be argued that in the study of Wang et al. (2015) the examined MBM of a (M)ETS is a form of a levy. However, our study, examines two totally different forms of imposed extra costs. It is necessary to construct a new detailed economic model so as to accomplish the aim of the paper by presenting the economic implications on the bulk shipping sector arising from two alternative levy schemes.

First of all, it is important to state that supply and demand for maritime transport are the key drivers for the determination of freight rates. The maritime transport industry consists of four interacting markets; the freight market, the shipbuilding market, the sale and purchase market and the demolition market. The freight market, the main source of revenue, plays the most important role in ship-owners decisions. The demolition market acts also as revenue source during economically tough times when ship-owners may decide to demolish inefficient and older vessels. Sometimes it can act as a relief instrument against industry´s overcapacity. However, in real life industry specific cases can be found when ship-owners hold on to older vessels in the hope of a market economic upturn. In the sales and purchase market the money transactions neither change the fleet capacity nor the industry owned cash amount. Money is spent by the ship-owners to purchase new vessels at the new building market. In the case where demand exceeds the supply of the industry and needs to be covered a freight rate rise is observed, leading consequently to a revenue increase. Subsequently, ship-owners are willing to pay higher prices for second hand vessels. However, when prices are extremely high new buildings are preferred. When the new ships are delivered, capacity is added into the sector, which drives freight rates to a decrease. In the case that ship-owners cannot remain active due to the financial downturn, they either sell or demolish ships seeking for revenues so as to manage to stay in the business (Grammenos, 2010; Stopford, 2009).

The behavioural factors of maritime transport companies and brokers may also influence the determination of freight rates in a small percentage, but we will not take this effect into account for simplicity reasons as also because this influence can be considered as negligible compared to the determinant role that supply and demand interactions have in the final price formation. Moving on to the factors that will be included, interactions in the sale and purchase market since they do not affect world´s fleet capacity will be ignored. Likewise, excluded from our model will be the new building market due to: a) it does not have an impact on the freight rates (in contrary freight rates is the underlying reason leading to new building investments) and b) funding provided from government may affect shipyard operations (Stopford, 2009).

Demand in our models is considered exogenous similarly to other studies e.g. Luo et al. (2009). Moreover, since the time factor is of vital importance for the application of the cobweb theorem it is appropriate to find the lead-time θ of a new order delivery since new capacity is introduced in the market. Usually it ranges between two to three years but in some situations i.e. during the last recession of 2008, lead-time may rise significantly. The market´s equilibrium is expressed by the equation: $Q_S^{FR} = Q_D^{FR}$

We assume that supply of shipping operations is influenced by the following factors: 1) world fleet capacity Z (deadweight), 2) New orders delivery N (deadweight), 3) Profit (US dollars). Since we will examine the

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enforcement of a levy scheme, the tax will be also included in the factors as T (US dollars); affecting the supply of shipping services through the Profit variable. Demand (W) as previously stated is considered exogenous and thus the freight rate function taking into account the above facts is expressed as: Freight Rate = f (Z, N, Profit, T, W)

We follow the assumption stated in Luo et al. (2009), based on the idea that high freight rates imply a high turnover for the business, and the total new order for ships for period t is stated as

$N_t = n \times \Pi_t$ (1),

where n is the average profits´ proportion accounting for new vessel purchase and Π stands for Profit, for which is

$\Pi_t = P_t W_t - (OC_t + F_t)\Psi_t$ (2)

where P=freight rates ($/ton), W= tons of bulk cargo carried, that we will take as the demand of shipping services and exogenous. OC accounts for vessel´s operating costs ($ per annum) such as crew costs and repairs, and are considered in the model as exogenous due to the fact that these are principally fixed costs. Equation (2) will not include all voyage costs, just only fuel costs as they account for the highest percentage of voyage costs (Psaraftis and Kontovas, 2013). Hence, total costs for ship-owners is given by the equation

$TC_t = (OC_t + F_t)\Psi_t$ (3)

Where, following Wang et al. (2015)

$F_t = \rho_t f_t \lambda_t S_t^3$ (4) and

$\Psi_t = \frac{W_t * d_t}{H_t * S_t * \rho_t}$ (5)

ρ accounts for operating time at sea (in hours), f is fuel price ($/ton), taken as exogenous since freight rates or fleet capacity do not have an influence on their price, λ the coefficient regarding the energy efficiency of a ship and S (knots) is average speed. Ψ refers to the number of ships required in order to satisfy demand and depends on d, which is the route distance (nautical miles) and H is ship's average capacity (tons). The change in fleet capacity is presented as:

$\Delta Z_t = Z_t - Z_{t-1} = N_{t-\theta}$ (6)

Hence, combining the above equations, a new dynamic one arises expressing the world bulk fleet:

$\Delta Z_t = n(P_{t-\theta} W_{t-\theta} - (OC_{t-\theta} - F_{t-\theta})\Psi_{t-\theta})$ (7)

The following step in our research is the application of the cobweb theorem. Hence, the freight rate change in international shipping following Luo et al. (2009) can be offered from the equation:

$\Delta P_t = \delta * (\Delta W_t - \varphi * \Delta Z_t)$ (8)

Where, following Luo et al. (2009), $\Delta P_t = P_t - P_{t-1}$, ΔW is the change in bulk cargo transported, ΔZ is the change in bulk fleet capacity, δ>0 refers to the freight adjustment factor on the basis of demand and supply alterations and φ>0 (constant) is the average fleet capacity utilization rate.

3.3 THE INTRODUCTION OF THE TWO LEVY SCHEMES

At the present paper we will examine the effects of two different tax-levy schemes: 1) a levy in the form of a specific unit tax, stated as TP, per ton of fuel and 2) in the form of an ad valorem tax, stated as VP, enforced as a percentage of fuel prices. We decided to choose the aforementioned tax schemes, as they would be directly imposed on the fuel costs of shipping operations. Thus, the principle of "polluter pays" is followed since these differentiated forms comply with IMO´s request to put pressure on carriers, aiming so at energy and operational

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efficiency enhancement. This is the underlying reason of preferring these schemes and not any other formula by way of an environmental tax imposed on freight rates or shipping revenues, as the main intention is not tax raising or raising a dispute between carriers and shippers.

Hence, if a levy scheme is introduced then we have the equations

$$\Pi_t = P_t W_t - (OC_t + \rho_t(f_t+TP)\lambda S_t^3) * \Psi_t \quad (9)$$

$$\Pi_t = P_t W_t - (OC_t + \rho_t(f_t(1+VP))\lambda S_t^3) * \Psi_t \quad (10)$$

Thus, equation (7) for the first case will be in the form of:

$$\Delta Z_t = n(P_{t-\theta}W_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}(f_{t-\theta}+TP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}) \quad (11)$$

In the same way, for the second levy scheme the new equation will be of the form:

$$\Delta Z_t = n(P_{t-\theta}W_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}f_{t-\theta}(1+VP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}) \quad (12)$$

We substitute ΔZ_t in the equation (8), for both cases. Hence, for the first scenario:

$$\Delta P_t = \delta(\Delta W_t - \varphi\Delta Z_t) = \delta\Delta W_t - \delta\varphi n(P_{t-\theta}W_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}(f_{t-\theta}+TP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}) \quad (13)$$

And for the second case we have:

$$\Delta P_t = \delta(\Delta W_t - \varphi\Delta Z_t) = \delta\Delta W_t - \delta\varphi n(P_{t-\theta}W_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}f_{t-\theta}(1+VP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}) \quad (14)$$

4. ECONOMIC IMPLICATIONS OF THE TWO LEVY SCHEMES

The ambition of every ship owner is to maximize profits. In our research we will not include the asset play case, which can occasionally result in high financial gains for ship owners, but we will focus only on the revenues gained from the trade activity. The logic behind this assumption is that industry´s fleet capacity during an asset play situation does not experience any change, remaining consequently constant. In order to proceed with the analysis, it is important to identify the values of Price (P) and Supply (Z) at the period t. The resultant equations based on the cobweb theorem show that these variables are dependent on their values at periods t-1 and t-θ. Since the proposed levy schemes are imposed at period t, the values for P_{t-1}, Z_{t-1}, $P_{t-\theta}$ and $Z_{t-\theta}$ are already known in the model as they account for the previous observed years, which are assumed in our model as exogenous, in which no tax costs had been previously included. Hence, being logical, the extra costs from both examined levy schemes do not affect these variables at periods t-1 and t-θ and thus will not have an influence on their values at least in the short term at period t. However, it is evident that the extra costs will affect these variables in the long term at the next stages of the cobweb model. Thus, the results that will be produced by our analysis account only for the short term and the examination of the implications of a levy scheme enforcement in the long term can be a suggestion for further research.

The sector´s profit with the inclusion of a bunker levy is calculated in equation (2) and for every levy scheme the profit maximization problem is

$$\Pi_t = P_t * W_t - \left(OC_t + \rho_t * (f_t + TP) * \lambda_t * S_t^3\right) * \frac{W_t * d_t}{H_t * S_t * \rho_t} \quad \text{(15) for the unit tax scenario}$$

$$\Pi_t = P_t * W_t - \left(OC_t + \rho_t * (f_t * (1 + VP) * \lambda_t * S_t^3\right) * \frac{W_t * d_t}{H_t * S_t * \rho_t} \quad \text{(16) for the ad valorem scenario}$$

Our assumption that the tax levy schemes are enforced at period t enables the usage of the cobweb model in the identification of the first order conditions of the profit maximization equations for the first and second levy schemes respectively as presented below:

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$$\frac{d\Pi}{dS} = -\frac{W_t * d_t}{H_t * \rho_t} * \left(2 * \rho_t (f_t + TP) * \lambda_t * S_t - \frac{OC_t}{S_t^2}\right) \quad (17)$$

$$\frac{d\Pi}{dS} = -\frac{W_t * d_t}{H_t * \rho_t} * \left(2 * \rho_t * f_t (1 + VP) * \lambda_t * S_t - \frac{OC_t}{S_t^2}\right) \quad (18)$$

Since the traffic volumes, the quantity transported (demand), fuel prices, operating costs, freight rates, fuel consumption and speed have non negative values, based on the equations (17) and (18) the optimal speed and fuel consumption of international shipping after a levy enforcement can be calculated as:

$$\tilde{S} = \sqrt[3]{\frac{OC_t}{2 * \rho_t * \lambda_t * (\text{f+TP})}} \quad (19.1) \quad \text{and} \quad \tilde{S} = \sqrt[3]{\frac{OC}{2 * \rho_t * \lambda_t * f_t (1+VP)}} \quad (20.1)$$

$$\widetilde{FC}_t = \rho_t * \lambda_t * S_t^3 \frac{\text{W*d}}{\text{H} * \tilde{S} * \rho} = \frac{\sqrt[3]{\left(\frac{OC_t}{2 * \rho_t * \lambda_t * (\text{f+TP}))}\right)^2}}{H_t} * \lambda_t * W_t * d_t \quad (19.2) \quad \text{and}$$

$$\widetilde{FC}_t = \frac{\sqrt[3]{\left(\frac{OC_t}{2 * \rho_t * \lambda_t * f_t (1+\text{TP}))}\right)^2}}{H_t} * \lambda_t * W_t * d_t \quad (20.2)$$

It is observable that the extra costs from the levies are imposed and added in the total fuel costs. In order to proceed, derivatives calculation of optimal speed and optimal fuel consumption with respect to fuel costs and industry´s energy efficiency for both cases respectively are required and presented as follows:

$$\frac{d\tilde{S}}{d(f+TP)} = -\frac{1}{3} \sqrt[3]{\frac{OC_t}{2 * \rho_t * \lambda_t * (f_t + \text{TP})^4}} \quad (19.3) \quad \text{and} \quad \frac{d\tilde{S}}{d(f + f * VP)} = -\frac{1}{3} \sqrt[3]{\frac{OC_t}{2 * \rho_t * \lambda_t * (f_t + f_t * \text{VP}))^4}} \quad (20.3)$$

$$\frac{d\tilde{S}}{d\lambda} = -\frac{1}{3} \sqrt[3]{\frac{OC_t}{2 * \rho_t (f_t + TP) * \lambda_t^4}} \quad (19.4) \quad \text{and} \quad \frac{d\tilde{S}}{d\lambda} = -\frac{1}{3} \sqrt[3]{\frac{OC_t}{2 * \rho_t (f_t + f_t * VP) * \lambda_t^4}} \quad (20.4)$$

The results of the above derivatives can be easily interpreted. Based on the indication that (19.3)<0 and (20.3)<0 and also due to the non-negativity of the included parameters, it is evident that either when fuel prices rise, in our case due to the enforcement of the levy schemes, or industry´s vessels efficiency decreases, ship operators will consequently will have to sail at a lower speed in order to deal with the extra costs. Additionally, this slow steaming mechanism will have an effect on fuel consumption, which will subsequently decline. The ratios of fuel consumption with the inclusion of the levy to fuel consumption without the levy, presented in (21.1) and (21.2) prove indeed that a bunker levy enforcement may force ship-owners to the cost minimization approach of a speed decrease.

$$\frac{\widetilde{FC}}{FC} = \frac{\lambda_t * W_t * d_t * \frac{\sqrt[3]{\left(\frac{OC_t}{2 * \rho_t * \lambda_t * (f_t + \text{TP}))}\right)^2}}{H_t}}{\frac{\rho_t * \lambda_t * S_t^3 * W_t * d_t}{H_t * \rho_t * S_t}} = \sqrt[3]{\left(\frac{f_t}{f_t + TP}\right)^2} < 1 \quad \text{(21.1) for the unit tax form levy}$$

$$\frac{\widetilde{FC}}{FC} = \sqrt[3]{\left(\frac{1}{1+VP}\right)^2} < 1 \quad \text{(21.2) for the ad valorem tax}$$

While a speed and fuel consumption decrease is illustrated as a way for ship-owners to cope with the levy costs two issues arise. The first is the identification of the speed change and its dependent factors, while the second deals with the change in the profit function of the bulk shipping industry, and will be described in the next section of the research paper. The proportional speed change, stated as M, as a result of the bunker levy implementation, using (19.1) and (20.1) respectively is presented as follows:

$$M = \frac{\tilde{S} - S}{S} = \sqrt[3]{\frac{f_t}{f_t + TP}} - 1 \quad \text{(22.1) for the unit tax scheme and}$$

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$M = \frac{\check{S}-\tilde{S}}{S} = \sqrt[3]{\frac{1}{1+VP}} - 1$ (22.2) for the ad valorem scheme

Even prior to this analysis, it would have sound as a logical expectation that a speed reduction would be the solution for minimising the extra costs. Yet, our findings associated with the speed change contribute to the existing research gap of this MBM enforcement in the shipping industry, as the dependent factors of this alteration for both examined levy schemes are identified. As far as the implementation of a levy in the form of a unit tax per bunker ton is concerned, the speed reduction of the industry´s carriers is dependent on fuel prices and the tax amount. Nevertheless, in the case where the levy scheme is applied in the form of an ad valorem tax, then speed reduction depends only on the percentage enforced by the policy makers. This is one of the main differences between the two schemes and a better grasp of this effect can be achieved through the graphical depiction example presented in graphs (2) and (3). Taken as bunker prices $234 per ton (a value that was actually observed during October 2015) and $400 per ton, different tax rates are examined. For the unit tax-levy scenario charges of $10, $30, $60 and $90 per ton of bunker fuel are imposed. As far as the ad valorem scenario is concerned, charges of 5%, 10%, 20% and 30% per bunker ton are chosen.

f ($/ton)	TP ($/ton)	M	f ($/ton)	VP (%)	M
234	10	1.39%	234	5	1.61%
234	30	3.94%	234	10	3.13%
234	60	7.33%	234	20	5.9%
234	90	10.28%	234	30	8.37%

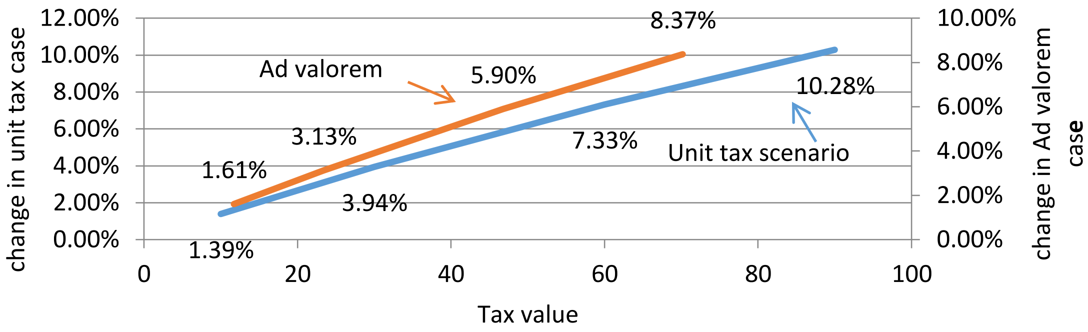

Figure 2: Speed reduction for a fuel price of 234$/ton

f ($/ton)	TP ($/ton)	M	f ($/ton	VP(%)	M
400	10	0.82%	400	5	1.61%
400	30	2.38%	400	10	3.13%
400	60	4.55%	400	20	5.9%
400	90	6.54%	400	30	8.37%

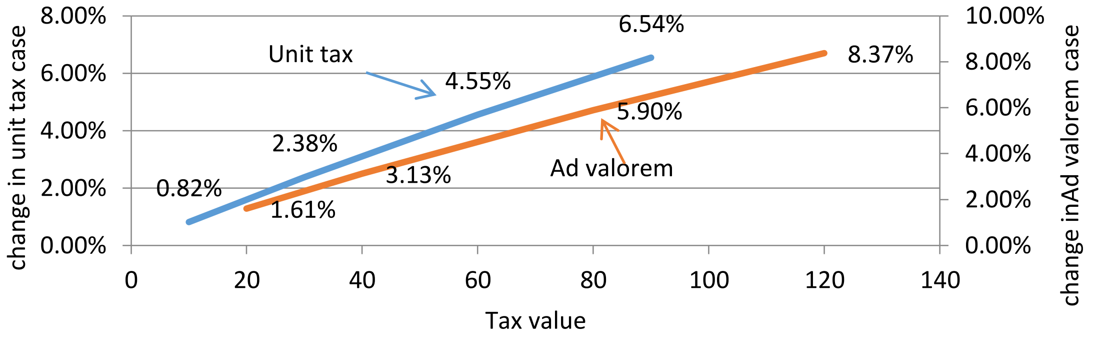

Figure 3: Speed reduction for a fuel price of 400$/ton

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Interpreting these findings, three main points are observed. Firstly, when having a low fuel price value, the unit tax scheme is more aggressive than the ad valorem leading to higher speed reduction. Contrariwise, when fuel price has a high value, then the ad valorem tax scheme acts more aggressive, requiring a higher speed decrease compared to the other scheme. Last but not least, as the speed change in the ad valorem scenario depends only on the percentage of the tax, neither a high nor a low bunker price value will have an influence in its final result.

5. PROFIT DIFFERENTIATIONS AND LEVY COSTS ALLOCATION

Having found the optimal speed and fuel consumption for both cases respectively, it is feasible to examine the influence of the proposed levy schemes on the industry´s profit. In order to proceed we insert the new values of $\widetilde{S}_t$ and $\widetilde{FC}_t$ into the Profit function, which we then derive with respect to the levy amounts. Hence, as far as the unit levy scenario is concerned

$$\frac{d\widetilde{\Pi}_t}{dTP} = -\left[\frac{W_t*d_t*\sqrt[3]{OC_t^2}*\sqrt[3]{2*\rho_t*\lambda_t}}{3*H_t*\rho_t*\sqrt[3]{(f_t+TP)^2}} + \frac{2*\rho_t*\lambda_t*W_t*d_t*\sqrt[3]{OC_t}}{3*H_t*\rho_t*\sqrt[3]{2*\rho_t*\lambda_t}*\sqrt[3]{f_t+TP}}\right] \quad (23)$$

and for the second scheme

$$\frac{d\widetilde{\Pi}_t}{dVP} = -\left[\frac{W_t*d_t*\sqrt[3]{OC^2}*\sqrt[3]{2*\rho_t*\lambda_t*f_t}}{3*H_t*\rho_t*\sqrt[3]{(1+VP)^2}} + \frac{f_t*\rho_t*\lambda_t*\sqrt[3]{OC_t^2}*W_t*d_t}{3*H_t*\rho_t*\sqrt[3]{(2*\rho_t*\lambda_t*f_t)^2}*\sqrt[3]{(1+TP)^2}}\right] \quad (24)$$

The remarkable finding of the produced derivatives for both levy schemes scenarios is their negativity. This can be interpreted as a levy market effect. Possible tax enforcement will result in the profits function decrease, which prior to this research might have been a logical expectation. Nevertheless, it is essential to examine how industry´s profit will changes for both levy scheme scenarios under differentiated levy values. The change in Profit is

$$N = \frac{\widetilde{\Pi}_t-\Pi_t}{\Pi_t} = \frac{OC_t*d_t*(S^{-1}-\tilde{S}^{-1})+d_t*\lambda_t*\rho_t*(f_t*S_t^2-(f_t+TP)*\widetilde{S_t^2})}{H_t*\rho_t*P_t-OC_t*d_t*S^{-1}-f_t*\rho_t*\lambda_t*S_t^2*d_t}$$ for the unit tax scenario

$$N = \frac{\widetilde{\Pi}_t-\Pi_t}{\Pi_t} = \frac{OC_t*d_t*(S^{-1}-\tilde{\tilde{S}}^{-1})+d_t*\lambda_t*\rho_t*f_t*(S_t^2-(1+TP)*\widetilde{S_t^2})}{H_t*\rho_t*P_t-OC_t*d_t*S^{-1}-f_t*\rho_t*\lambda_t*S_t^2*d_t}$$ for the ad valorem scenario

As far as the above levies´ influence in the industry´s profit is concerned a sharper view is provided by the following illustration in figure (4). The data for the year 2007, presented in Wang et al. (2015), are used for simplicity reasons; Sailing speed prior the tax is S=14kts, ship size used H=49,000 tons, ρ= 6,480 hours, demand of the industry W=4,100 million tons, average voyage distance d= 9,036 nms, f=350$/ton, ship´s efficiency λ=0.0012, P= 48$/ton and annual operation costs of ship OC= $1.51 x 10^7. It is observable in figure 4 that the enforcement of a ad valorem scheme would lead to a higher profit loss in the bulk shipping industry.

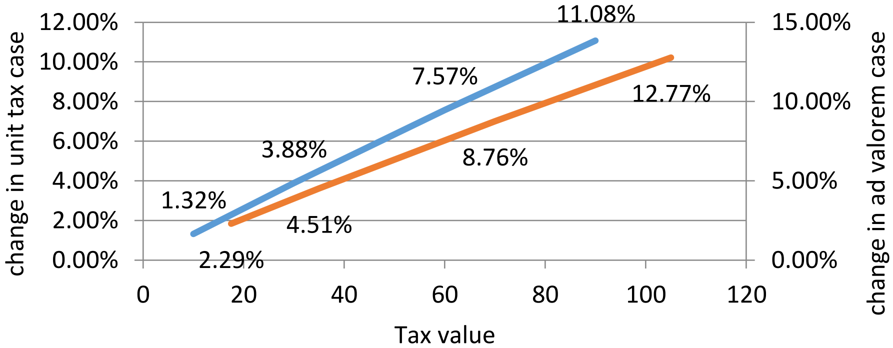

Figure 4: Profit reduction in both levy schemes

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As previously stated, one of the two aims of this research paper is to investigate how costs are allocated among the actors involved in the shipping industry i.e. who actually bears the burden of the tax. Hence, based on the cost-pass through theory, it is understandable that the estimation of the price elasticity of supply and demand is prerequisite. The price elasticity of supply and demand is generally presented as:

$E_s=\frac{\%\Delta Z}{\%\Delta P}=\frac{\%\ change\ in\ quantity\ supplied}{\%\ change\ in\ price}$ and $E_d=\frac{\%\Delta W}{\%\Delta P}=\frac{\%change\ in\ quantity\ demanded}{\%change\ in\ price}$

The following step of our analysis would be to estimate theses variables based on the cobweb model in the long-term, but we will not get into this analysis as our aim at this point is to present the general framework of how levy costs will be allocated. For this part of our study we assume that at the periods t-1 and t-θ the levy schemes had already been enforced, aiming so to illustrate in equations (25) and (26) the amount of the extra costs that will be borne by the shipper and ship-owner at period t. Thus, the actual amount borne by the supplier, in our case the ship-owner, is calculated as:

Fraction of the levy costs= $\mathrm{E}_d/(\mathrm{E}_d+\mathrm{E}_s)=\ (\Delta \mathrm{W}_t * \mathrm{Z}_{t-1})/(\Delta \mathrm{Z}_t * \mathrm{W}_{t-1}+\Delta \mathrm{W}_t * \mathrm{Z}_{t-1})$ (25)

In the same way, the fraction of the levy costs borne by the consumer, in our case the shipper is presented as

Fraction_2= $\mathrm{E}_s/(\mathrm{E}_d+\mathrm{E}_s)=\ (\Delta \mathrm{Z}_t * \mathrm{W}_{t-1})/(\Delta \mathrm{Z}_t * \mathrm{W}_{t-1}+\Delta \mathrm{W}_t * \mathrm{Z}_{t-1})$ (26)

The enforcement of a levy scheme in the shipping industry is numbered among the industry-wide cost pass-through situations since the cost change has an effect on all involved firms (shipping companies). It is important to highlight that the extent of the cost change is passed to consumers (shippers) by the firms can differentiate among them. The cost pass through fraction of a tax is dependent on the price elasticity of supply and demand.

At this point it would be interesting to observe how the fractions alter depending on the market situation. Therefore, an example of two different periods; 2012-2013 and 2006-2007 is presented. The data are taken from UNCTAD´s maritime reviews. It is obvious that if the levy schemes had been enforced at those periods the values of the fleet capacity and freight rates would have been different. However, we use those data for simplicity reasons so as to reflect only the weight of the market situation on the differentiation between the fractions. In the first period Z_{2013} =725.010.000 dwt, Z_{2012} = 684.600.000 dwt, W_{2012} = 4.322.580.645 tons and ΔW = 2.377.419.355 tons (UNCTAD, 2014; UNCTAD, 2013). Inserting this data into (25) and (26), the fractions are quantified. Fraction absorbed by ship-owners = 90.3% and the fraction borne by shippers = 9.7%. It is observable that the extra costs from a possible tax enforcement had to be absorbed mainly by the carriers.

This result may seem odd at the beginning. However, based on the fact that it depends entirely on the price elasticity of supply and demand and taking into consideration that currently the shipping industry is suffering by overcapacity and low freight rates, the result can be justified. This can be also supported by the second example for the years 2006 and 2007, when W_{2007}= 2 billion tons, W_{2006}= 1.8 billion tons, Z_{2007}= 361,928 thousands dwt and Z_{2006}=338,107 thousands dwt (UNCTAD, 2007). The results show that 52% of the levy costs had to be borne by the shippers. Hence, it can be stated that when the financial situation of the industry is prosperous, with high demand that needs to served and high freight rates, as it was for those two years, a higher percentage of the extra costs can be passed to the shippers.

6. CONCLUSION

The research paper focused on the resultant economic implications from the introduction of a bunker levy scheme in the bulk-shipping sector. Two alternative forms of tax, a unit and an ad valorem, were examined and benchmarked. A dynamic economic model was constructed for the main analysis. Despite that many models have already been designed for the representation of the supply and demand functions of the maritime transport business, none accounted for a tax scheme. The model proposed makes use of the cobweb theorem, which until now was only recommended for forecasting.

The model provides the basis for the benchmark of the two levy schemes. In both cases, the extra costs are added in the fuel expenses. A speed optimization (through a reduction) by the carriers can be a solution for

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minimizing those charges. Another tactic could be an increase of the sectors energy efficiency. Even prior to our analysis, a speed decrease would had been expected as a possible solution, since it would consequently lead to a decline in fuel consumption. However, our analysis adds value to the industry since one of its main findings is the identification of the factors that determine this speed change. In the case of the unit tax scenario, the change is altered depending on the values of fuel price and the fixed amount of tax. Nevertheless, in the ad valorem case, it relies upon the percentage set up as the tax scheme and fuel prices have absolutely no influence whether they have a high or low value.

Similarly, our analysis proved the profit decline subsequent to the levy schemes enforcement. Interrelated with this decrease, the framework for identifying how the extra costs are allocated in the industry was presented. Since the price elasticity of supply and demand is the determinant factor for this allocation, it is indicated that when the market situation is prosperous, with high freight rates and without suffering from overcapacity, the extra costs can be transferred from ship-owners to shippers easier than in the situation when the industry is in a trough or recession.

Our study fills in a part of the research gap regarding the implementation of market based measures in the shipping industry. It adds value not only to the academic community, but also to the real life industry. From one side, policy makers can benefit at their effort in the examination of MBMs and from their side, ship-owners are informed about the implications of the two examined levy schemes; thus being able of acting proactively in order to minimize their costs. Suggestions for further studies could be the identification of the long-term welfare implications of the levy schemes or the examination of other forms of environmental tax schemes.

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