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Are Exit Decisions Capital Replacement Decisions? Evidence from the Tanker Industry

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ABSTRACT

This paper presents a structural model for the exit process of heterogeneous agents in which assumptions of market organization affect economic behavior. In this framework the market for oil tanker carriers provides a unique paradigm for an empirical assessment of the impact of financial versus capital replacement variables on exit behavior under perfect competition. In this setting we challenge Koopman's earlier assertion (Zannetos, 1966) that namely exit decisions correspond to capital replacement. Aggregate models of exit are proposed and brought to real data in the tanker market industry. Their specification is tested through econometric methods and appears very sympathetic to scrapping dynamics. The empirical findings verify the abundance of financial variables over capital replacement, as well as the importance of market organization on capital investment decisions.

JEL Classification: *C51, C52, L92*

Keywords: *Exit decisions; Agent heterogeneity; Count data; Firm uncertainty; Hausman test*

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I. INTRODUCTION

Despite the profound importance of entry and exit on economic activity and development, research on these economic decisions has either been carried out in the context of general equilibrium growth models with firm level uncertainty (Krieger, 2002, p.121) or in the context of analyzing equilibrium strategies in a dynamic game (Pakes, 2000). In a very innovative paper Krieger relies on the work of Dixit and Pindyck (1994) on industry equilibrium under uncertainty. He derives a rational expectations general equilibrium model with heterogeneous agents, where aggregate scrapping reorganizes the economy by shifting capital from low productivity firms to high productivity firms. In there series of papers, Pakes (2000) and his collaborators propose a framework for the analysis of firm dynamics under strategic behavior. Both approaches are computationally intense. They build on rational expectations and require that economic agents make correct guesses on the stochastic process of prices when they formulate their optimal policies. Under strategic behavior additional knowledge of the dynamics of firms is assumed. These aggregate policies in turn determine the "assumed" process. This requires the computation of a fixed point in functional spaces and the associated difficulties are highlighted by Dixit and Pindyck (1994, p.253). The described technical limitations complicate the task of testing empirically the factors that determine the economic nature of investment/disinvestment behavior, as well as the impact of market organization on such actions. Therefore, most empirical studies on investment behavior focus on dynamic aspects of firm decisions by means of econometric techniques, without taking into account the market structure in which agents operate (Corres, Hajivassiliou and Ioannides, 1997), (Whittle, 1997).

Moreover, empirical research on firm dynamics has mainly focused on the impact of several macroeconomic variables. To the knowledge of the author very few studies have examined empirically the economic behavior of investment and disinvestment actions and the interrelated effects of market structure on these decisions. A recent innovative approach is the paper by Gatti, Gallegati, Guilioni and Palestrini (2002), where the entry and exit process is affected by financial conditions and exit is determined endogenously.

In this paper we focus on the economic motivation behind exit decisions in a perfectly competitive market. We derive aggregate structural models of exit under perfect competition. This takes the burden of the computation of equilibrium in super games under strategic interaction. The introduced models accommodate the impact of market organization on the nature of economic decisions and the microeconomic relationship between market exit, capital replacement, organized markets and economic performance.

As discussed in Blanchard and Fisher (1998, p.291-293) "we cannot develop a theory of investment independently of the market structure in which the firm operates". The tanker market industry, namely the market of vessels that carry oil, provides a unique paradigm for our analysis, as well as the necessary organizational framework for the derivation of models of exit with agent heterogeneity without strategic interaction. Before proceeding with the aggregation exercise and model estimation, we discuss our motivation behind the specific choice of this market for tanker vessels and explain why it provides us a unique paradigm for addressing the previous questions.

The paper is organized as follows. In Section II we introduce the tanker market industry and discuss our motivation behind this particular choice. We discuss the available data, as well as Koopmans' (Zannetos, 1966) assertion on the relationship between exit and capital replacement. In Section III aggregate structural models of scrapping activity are derived and employed to test whether scrapping decisions correspond to capital replacement or exit. In Section IV we derive and estimate models for aggregate scrapping data with agent heterogeneity under uncertainty and irreversibility and identify the relevant variables for decisions of exit. Assumptions of the existence and completeness of financial markets crucially determine the form of the models. In Section V we discuss the conclusions and topics for further research.

II. THE TANKER INDUSTRY

"...why should he order a replacement if the prospects for employment of the new vessel when it appears in the market are not promising? Would he not naturally wait until he is somehow assured about the immediate future?", Zannetos (1966, p.120)

The oil tanker industry is a unique paradigm of perfect competition. As discussed by Strandenes (2002, p.186) there are remote limits to entry in the tanker market industry. Information is publicly available to all investors in this market and the cost of exiting is fairly low. Organized shipbrokers operate in markets for ships; they collect data and information and take care of the allocation to agents in this industry. All these characteristics indicate a well functioning market. This has a profound impact on the models presented in this paper and highlights the importance of market organization and structure on economic behavior.

The specific market structure of this industry allows us to forego issues of strategic behavior and furthermore we may assume that all relevant variables are exogenous with respect to the decisions of operators. Especially the scrapped tonnage each period is a very small fraction of the existing fleet. This observation justifies the assumption on the exogeneity of freight rates (economic rent to vessels) with respect to scrapping dynamics.

Owners have the option to exit the market by selling their vessel for scrap or by selling it in the market for second hand vessels. Besides the active second hand market, an organized market for future and forward contract exists. The latter guarantees the existence of a set of spanning assets that allows owners to span uncertainty in this market. Their existence validates the assumption of market completeness that will be crucial for the specification of our models and characterization of structural agent heterogeneity. All the above explain the motivation of economists to employ the tanker industry for modeling decisions of entry, exit and lay-up (Dixit and Pindyck, Chapter 7). Tanker freight rates determine the revenue (rent) a ship earns for servicing a particular contract for a pre-specified period of time and vary with duration and vessel type. They are fairly standardized, quoted in terms of U.S. dollars per day and the market for one-year time charter contracts is well organized and liquid. Time charter rates are paid to the owner of the vessel, who is then liable for the operating expenses (crew, port expenses and bunkers). The difference between rates and operating costs determines the earnings before taxes, interest and depreciation.

This link between the scrapping and second hand market, corresponds to the choice between scrapping versus selling the vessel for further operations and has a unique impact on the formation of the introduced models. Furthermore, it provides additional motivation for the implications of economic and market organization on economic behavior. As discussed by Strandenes (p.197) the scrapping market is fairly competitive and has remained so for a long time.

Traditionally, the tanker industry has provided economists with a framework for analyzing the nature of investment activity, since the early thirties. In his seminal doctoral thesis Zannetos (1966) contradicted Koopman's earlier assertion "that the conditions which simulate new investment also favor replacement" (Zannetos (1966), p.119). According to his argument "there is no theoretical reason requiring sale or retirement of a vessel only after an order for its replacement has been placed or the replacement itself has been received...there is no reason why the placing of an order or the receipt of a presumed replacement should cause the economic value of an existing vessel to vanish". Zannetos' argument is in line with the postulates of neoclassical economics; an agent will exit the market only when the value of remaining active is below a threshold, which implies that exit decisions are not necessarily capital replacement decisions. This hypothesis will be empirically tested in this paper and the structural framework for the empirical work is very sensitive to our assumptions on market structure and organization.

Zannetos goes one step further and concludes: "We are confident that data would have refuted such a hypothesis...At low rates, when most of the retirements will take place because of the expiration of the economic value of vessels, retirements may only reduce existing surpluses." Once we have derived models for aggregate scrapping data we will formally test the above: we will namely test the statistical significance of pending orders, which is expected to be zero and of time charter rates, which should be negative. Finally, one implication of the above discussion is that the age of the fleet has only an indirect effect on scrapping dynamics. In periods of low rates older vessels are more likely to be scrapped, since they have a lower economic value, due to higher operating costs. In periods of high rates, age is not expected to have a significant effect on scrapped tonnage. Since the age of the fleet is not directly observable, we will not be able to test formally this hypothesis, but only indirectly through the impact of pending orders.

In her recent study Strandenes (2002) challenges the view mandating synchronization between the scrapping and new building market and argues that exit decisions should correspond to capital replacement decisions if there was no uncertainty regarding the economic and technical life of vessels. Going one step further she indicates that scrapping market fluctuates, given the prevailing conditions in the freight markets. A formal test of the abundance of financial variables over technical requires the derivation of structural aggregate models, consistent to the structure and organization of this particular market. Furthermore, the specific characteristics of competition provide a unique paradigm for our understanding of the economic behavior of exit.

There are four general sizes of oil tankers depending on their tonnage capacity. Revenue freight rates, operating costs, construction (newbuilding) prices of new vessels and prices of vessels in the second hand market, do not depend linearly on tanker capacity. Regarding the *data*, the main source is Marsoft, (Boston) Inc. and it is the same source used by Dixit and Pindyck in Chapter 7, p.238. Marsoft provided the *scrappin*g data (the tonnage scrapped) for tanker ships. This data set is accurate and precise. It is in quarters from 1980 until the third quarter of 2002. This implies that we are given 91 observations for all types of tanker carrier. For this time period the data on time charter rates are fully available and precise, but NOT the scrapping prices. The operating costs are fairly straightforward, once the age of each vessel is known. Since the average age of the fleet is not known, we use a category weighted index for the operating expenses. Unfortunately scrapping data (data for tanker vessels withdrawn from the market and sold for scrap) do not exist for each category, but either as aggregate number of vessels or tonnage capacity scrapped.

One main characteristic of the scrapping observations is that the data set appears to have threshold-type characteristics, due to the interactions and adverse effects of the three different forces (exit, capital replacement, technical obsolescence) that drive scrapping decisions. After the 26th observation the dynamics of the process appear to change and the intuition for explaining this pattern is as follow: For the first 26 observations time charter rates are at historically low levels and economic returns are significantly low (the market is in a recession; later on we shall make this selection argument more formal and give a quantitative justification in the Appendix). Low returns indicate that it is more profitable to exit than to remain in the market and therefore the "exit" effect is the key explanatory factor for our scrapping data. Once returns become significant the pattern of scrapped tonnage dynamics changes; the "exit effect" becomes less predominant compared to the capital replacement effect, as well as natural depreciation. However, both series have a natural scrapping trend clearly interrelated to the obsolescence of the fleet. In the bear-market regime the trend is higher and decisions due to the exit effect exhibit higher volatility, whereas in the bull-market regime, the trend is lower and exit decisions are less volatile, or outbalanced by capital replacement decisions. Our main task will be to develop structural models that will be sympathetic to the empirical facts demonstrated by the data and allow a test on the nature of the economic behavior of exit and the impact of market organization and structure on these decisions.

III. MODEL I: A MODEL OF HETEROGENEOUS AGENTS

We now proceed with the presentation of aggregate models for exit (or scrapping) decisions in the tanker industry, which may be easily extended to most competitive markets. Intense competition implies that the number of exits has no short term impact on profitability and time charter rates (rents for the vessel), which are explicitly determined in the freight rate market, by the charter and lay-up decisions agents undertake. One important complication is that scrapping data and prices do not exist for each category and therefore we are forced to work with aggregate data across categories[1]. Based on the proposed aggregate models we shall address issues of economic behavior with homogenous and heterogeneous agents and test the assertion that namely exit behavior does not correspond to capital replacement, understand the effects of market organization on exit and identify the main forces of exit in a micro econometric framework. Although exit or entry decisions correspond to discrete events, count data models have found limited application in modeling such actions. Count data models were introduced in the seminal paper by Hausman, Hall and Griliches (1984) for analyzing the effects of research on the number of patents. Since the number of vessels scrapped each period are discrete, we assume that the number of scrapped vessels for each category (we assign for categories of vessels, based on tonnage (capacity)) follows a Poisson process and consequently the sum across all categories is the sum of Poisson processes following a Poisson process, too (The distribution of the Poisson random variable and the associated properties are presented in Appendix A). We shall now derive the dynamics of the aggregate scrapped tonnage and then we shall discuss the structural specification of the intensity of the Poisson process, which depends on the market structure and organization, the expectations of agents and the law of motion for the population of agents. Hereafter, we use the following Poisson specification, namely:

$$D_{scr}(t, T+T) \sim P(\lambda_t) \tag{1}$$

In the above specification $D_{scr}(t,t+T)$ denotes the number of vessels scrapped for all categories between t and t + T and λ_t denotes the intensity of the Poisson process as defined in Appendix A. We now proceed with the structural framework that determines the intensity of the process. In a partial equilibrium framework, we assume n agents, whose probability of exiting or staying in the market is fully determined by the structural error, the value of staying in the market under a charter rate (V_{stay}) and the value of scrapping the vessel (V_{exit}) and foregoing the revenues from the freight rate market. This probability π_{stay} of remaining in the market, under the assumption of type I structural errors is given by:

$$\pi_{stay} = \frac{\exp(V_{stay})}{\exp(V_{exit}) + \exp(V_{stay})} \tag{2}$$

We assume n heterogeneous agents with exponential utility and we suppress the index for each agent hereafter. Each agent has a value V_{eq} for which he is willing to sell his vessel in the second hand market and exchange for this certain equivalent the **option of waiting and either operating or scrapping the vessel**. The utility from this value is then equal to the expected utility from remaining in the market and operating the vessel and the value of the option to scrap the vessel and exit the market:

$$-\exp(-V_{eq}) = EU(V) = \pi_{exit} U(V_{exit}) + \pi_{stay} U(V_{stay}) \tag{3}$$

Furthermore, we assume that the number of vessels each agent scraps follows a Poisson process with intensity λ and the probability of no exit (zero counts of scrapped vessels), which equals the probability of staying in the market for each agent, is given by:

$$\pi_{stay} = \exp(-\lambda) \tag{4}$$

$$\exp(-V_{eq}) = \frac{\exp(V_{exit})}{\exp(V_{exit}) + \exp(V_{stay})} \cdot \exp(-V_{exit}) + \frac{\exp(V_{stay})}{\exp(V_{exit}) + \exp(V_{stay})} \cdot \exp(-V_{stay}) \Rightarrow \tag{5}$$

$$\exp(-V_{eq}) = 2 \cdot \exp(-\lambda) \cdot \exp(-V_{stay}) \Rightarrow \tag{6}$$

$$\lambda = \ln 2 + V_{eq} - V_{stay} \tag{7}$$

The intensity of the scrapping process is equal to the difference between the price of the vessel and the value of operating the vessel under a long term contract, whilst foregoing the option to scrap [2]. The existence of organized markets for the second hand price of vessels implies that there is an equilibrium price for the price of the vessel, which is V_{eq} and aggregates in equilibrium all agents' expectations. The natural question is then the following: ''If all agents agree then why do they trade in this industry?" The answer is simple: they trade due to global portfolio restructuring decisions and re-allocation of funds. Although this partial equilibrium model aims at offering a good explanation on exit behavior, the impact of market structure on exit behavior and the driving forces behind exit it does not explain risk allocation decisions, which make agents trade, despite their agreement on market prices. Furthermore, the value from staying in the market under a long term contract and foregoing the option to scrap is fully determined by the long term contracts and the assumption on market completeness, which allows agents to span the value of all risky payoffs. The non-negativity of the intensity is guaranteed by the fact that the value of the vessel V_{eq} in a complete market always exceeds the value from operating the vessel V_{stay}, **as the latter does not include the option to scrap the vessel** V_{opt} (fixing the vessel under a time charter contract and receiving the rent (freight rate) for the services provided, the owner foregoes the opportunity of scrapping the vessel until the time charter contract expires). In equilibrium, in order to avoid arbitrage opportunities $V_{eq} = V_{stay} + V_{opt}$. In this simple model the intensity of exit is the same across heterogeneous agents.

The key conclusion of this simple model of heterogeneous agents is that under the existence of organized markets and convergence of beliefs, investor heterogeneity does not have a significant impact and the intensity of the process of the number of scrapped vessels remains multiplicative in the number of agents. Consequentially, $D_{scr}(t, t + T)$ follows a Poisson process $P(\lambda_t)$ with intensity $\lambda_t = \lambda \cdot n \Rightarrow \lambda_t = (\ln 2 + V_{eq} - V_{stay}) \cdot n \Rightarrow \lambda_t = (\ln 2 + V_{opt}) \cdot n$. (See Appendix A) This specification implies that the conditional mean of the scrapped vessels is equal to the difference of V_{eq}-V_{stay} (the option to wait) times the number of agents in this market and is very intuitive, from an economic point of view: It implies that agents exercise their option to scrap the vessel, when scrap prices and uncertainty is high or when the strike price (the value from remaining in the market and fixing the vessel under a time charter rate) remains low. In the next section we shall demonstrate that unlike investor heterogeneity, the evolution of the population of the number of agents n is crucial to the specification of this model.

The structural derivation of the Poisson process provides significant insight into the factors that determine the exit process. However, as category specific data are not available and the number n of agents is unknown, it is difficult to acquire further structural insight into the specification of λ_t. Hereafter we assume a homogenous reduced form exponential specification for λ_t. Before proceeding with the estimation of our count data models, let us discuss the motivation behind the choice of the exogenous variables in the specification of the intensity. The tanker sector has always been considered as a paradigm for perfect competition with three main incentives to exit the tanker market: The first and most important is the pure exit decision (of financial nature); the second reason is capital replacement, whereas the third reason, which is clearly interrelated to the "demographics" of the fleet, is physical depreciation and technical obsolescence. The impact of these three different forces on the dynamics of scrapped tonnage will not be uniquely determined.

We now proceed with the estimation of the model; with Y_t the aggregate number of vessels scrapped at period t and X_t the set of the exogenous variables. We estimate the Poisson specification by Maximum Likelihood with an exponential reduced form for the intensity, namely:

$$Y_t \sim P(\lambda, n), \lambda_t = \lambda \cdot n = \exp(X_t^{'} \cdot \beta) \tag{8}$$

The Poisson specification implies that the conditional mean (which is $E[Y_t \mid X_t] = \exp(X'_t \cdot \beta)$) is equal to the conditional variance, which is a restrictive assumption.

Therefore we estimate the model with Non-Linear Least Squares, namely:

$$Y_t = \exp(X_t^{'} \cdot \beta) + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2) \tag{9}$$

We now perform the estimation of the model, which is a Poisson model with the standard exponential specification for the intensity with the number/tonnage of scrapped vessels scr as the dependent variable and the following exogenous variables for X_t:

1. tci and opi (deadweight weighted indices of the time charter rate and operating expenses for each category) that determine the value from operating the vessel V_{stay} the existing tonnage
2. fleet, the total tonnage, as a proxy for the rate of physical depreciation
3. new the pending tonnage on order, as proxy for capital replacement decisions
4. scrk lags of the dependent variable scr
5. oil, spoil indexes for the price of oil and bunkers as instruments for the unobserved market price of scrap and:
6. air, an index for air transportation. Finally we include a time trend and the constant term cons.

We shall now include one more "q-type" variable as a proxy for the prices of second hand vessels that determine V_{eq}. According to the Marshallian rule of investment (Dixit and Pindyck, 1994), under certainty the ratio $\frac{\text{tcrate} - \text{opex}}{\text{new}}$ is the yield of the investment and investment should only be undertaken, if this yield exceeds the risk free rate. The inverse of this yield is a proxy for the time needed to recover capital and it is similar to the P/E ratio used in finance. This ratio will be named capital replacement ratio (crt hereafter) and will be included in the set of regressors. We now proceed with estimating (7, 8) and display the results in Table 1.

Table 1

Model	PQMLE Eq. (8)	NLLS Eq. (9)
scr1	.0204 (.0301)	.0090 (.0407)
scr2	.1069 (.0252)	.0770 (.0239)
tci	-0.0000214 (.0000126)	-.0000268 (.0000149)
opi	.0002094 (.0001052)	.0001714 (.0001123)
crt	.00815 (.00457)	.00674 (.00397)
new	-.0488 (.0320)	-.0552 (.0396)
fleet	.000942 (.0063)	-.000899 (.0080)
oil	.00837 (.0152)	.01248 (.0193)
spoil	-.00596 (.0043)	-.00649 (.0046)
air	.00168 (.0014)	.00162 (.0018)
time	-.00396 (.0114)	-.00237 (.0137)
cons	-.4063 (1.527)	.5927 (1.992)

The Likelihood of the Quasi Maximum Likelihood Estimate has a value of LP QMLE = 145.9 and a Pseudo-R^2 =0.2495, which is particularly low, whereas the Wald statistic for the joint statistical significance of the coefficients is 221.04 and accepts the specification with probability one. For the Non -Linear Least Squares model the Log Pseudo-Likelihood is LNLLS = 157.1 and the Pearson statistic is 2.31, which is relatively close to one. Before analyzing and discussing the results we perform additional specification tests. We perform a Hausman test between the two models and the test has a χ^2 (9) = 0.44, which implies we should not reject the model. However, by inspecting the residuals, the model clearly fails to fit the data and it systematically under predicts the scrapped tonnage, especially for the first 26 observations, where tonnage activity is really high. What is even more puzzling is that the model predicts the correct sign of the innovations $scr_t - scr_{t-1}$ for 24 out of the 26 first observations, whereas it clearly fails to predict the scrapped tonnage. For the subsequent observations, the model does much better in predicting the scrapped tonnage, but clearly fails to assign the correct sign to the predicted innovations.

In order to take care of feedback effects we include two lagged endogenous variables in the regressors, which under auto correlated errors will lead to inconsistency. To account for this source of endogeneity we include the two lags of the estimated residuals in the regressors and repeat the estimation of Eq.(8) and Eq.(9). Results are displayed in Table 2.

Only in the Poisson Quasi Maximum Likelihood estimation the second lag of the residual appears statistically significant; however we perform a Hausman test and the test is a χ^2 (9) = 0.44, which still implies we should not reject the model. Although the model is incapable of fitting the data, all coefficients have the right sign; it fails to account for the volatility displayed by the data, especially for the first 26 observations. In order to allow for overdispersion of the data, we estimate the Negative Binomial Model that does not impose equality between the conditional mean and the conditional variance [3], as well as Ordinary Least Squares.

Table 2

Model	PQMLE Eq. (8)	NLLS Eq. (9)
scr1	-.0277 (.2151)	.0747 (.2669)
scr2	.3939 (.1534)	.344 (.2771)
ures1	.0272 (.2348)	-.0952 (.2910)
ures2	-.3215 (.1611)	-.3018 (.3042)
tci	-.0000218 (.0000116)	-.0000184 (.0000152)
opi	.0002208 (.0001132)	.0002096 (.0001132)
crt	.00564 (.00454)	.00530 (.00403)
new	-.0536 (.0359)	-.0675 (.0530)
fleet	.00259 (.0055)	-.00051 (.0073)
oil	.00234 (.0140)	.0086 (.0172)
spoil	-.00841 (.0050)	-.00998 (.0058)
air	.00142 (.0014)	.00162 (.0017)
time	-.00384 (.0110)	-.00578 (.0129)
cons	-.6741 (1.329)	.4333 (1.684)

Table 3

Model	PQMLE Eq. (8)	OLS
scr1	.0204 (.0301)	-.0111 (.1116)
scr2	.1069 (.0252)	.3556 (.0925)
tci	-0.0000214 (.0000126)	-.0000731 (.0000386)
opi	.0002094 (.0001052)	.0003771 (.000358)
crt	.00815 (.00457)	.0546 (.0215)
new	-.0488 (.0320)	-.1039 (.0665)
fleet	.000942 (.0063)	.0002 (.0239)
oil	.00837 (.0152)	.0296 (.0467)
spoil	-.00596 (.0043)	-.0156 (.0109)
air	.00168 (.0014)	.0048 (.0050)
time	-.00396 (.0114)	.0116 (.0437)
cons	-.4063 (1.527)	-.4864 (5.629)
R^2	.2145	.6660

Although the Negative Binomial model does not improve our results significantly, what seems encouraging for the exponential specification is the fact that all regressors have the right sign, in line with the principles of neoclassical investment theory: The tci has a negative effect on exit decisions (low rates result in lower values for the V_{stay}, which corresponds to a lower strike price for the option to scrap and consequentially higher exit rates), opex (which contributes negatively to V_{stay}) has a strong positive effect, implying that operating costs are far more significant for the exit decision than income, crt has a positive effect, since higher capital replacement periods make the industry less attractive and finally pending orders new have a negative impact, which implies that exit decisions in this industry are not due to capital replacement. Finally, the constant appears statistically insignificant for all specifications.

Having completed specification and estimation let us now discuss our results.

Although the count data models survive the various specification tests, we are still facing two significant drawbacks: On the one hand the models seem unable to predict the large number of exit decisions, especially in the periods of low rates. On the other hand, one structural implication of the above specification is that the coefficients of tci and opi have to be of comparable magnitude, as their difference determines the value from operating the vessel V_{stay}. This is clearly violated by the results presented in Table III. We shall now try to relax some of the assumptions of our model, in order to induce more volatility and avoid the restrictive assumptions on the process of agents.

IV. MODEL II: EQUILIBRIUM MODELS OF EXIT

In this section we assume heterogeneous agents with a stochastic evolution for the number of agents n.

We remain now in line with our previous analysis; namely heterogeneous agents who scrap their vessels according to a Poisson process with intensity $P(\lambda)$. We adopt one simplification and assume that the difference between the second hand value of the vessel and the value of staying in the market and fixing it under a long term contract (this difference is equal to the option to wait) is constant and does not vary with time. This implies that the Poisson intensity is constant and it will be denoted λ_p hereafter. We go one step further (hereafter dW^t stands for the innovation of a standard Brownian motion) and assume the following reduced form for the evolution of the number of agents n in this industry:

$$dn = n \cdot \mu_n(n)dt + n \cdot \sigma_n(n)dW^t \tag{10}$$

where the above population equation admits the factor representation:

$$n = \frac{1}{\hat{\lambda}}\exp(C \cdot X_t) \tag{11}$$

And X_t is the state vector of all exogenous variables and summarizes all the uncertainty regarding the dynamics of the population. We assume that X_t evolves according to the following Stochastic Differential Equation:

$$dX_t = \mu_x(X) \cdot dt + \sigma_x(X) \cdot dW^t \tag{12}$$

Then we can express the terms $\mu_n(), \sigma_n()$ in terms of μ_X and σ_X simply by applying Ito's Lemma (Dixit and Pindyck, 1994). As shown in the previous section, the mean of the number of vessels scrapped Y_t (conditioned on the stochastic number of agents) has now the following compact form representation:

$$E[Y_t \mid n] = \hat{\lambda} \cdot n = \exp(C \cdot X_t) \tag{13}$$

with X_t the Markov process that summarizes all the factors that determine the evolution of agents: $dX_t = \mu_x(X) \cdot dt + \sigma_x(X) \cdot dW^t$.

We consider estimation of the wider model that includes the previous conditional mean specification as a special case:

$$Y_t = \exp(C \cdot X_t) \tag{14}$$

Where X_t is an Ito process, which as proved by Tong (1983) admits a discrete time Markov process approximation:

$$X_t = A \cdot X_{t-1} + B \cdot v_t, \quad v_t \sim N(0, \sigma^2) \tag{15}$$

At this point we should note that Dixit and Pindyck (p.268) derive this specification in a general equilibrium framework. They assume that the state variable X_t is firm specific uncertainty and any one firm's inverse demand curve becomes P = X D(Q). They then construct a two-stage general equilibrium model with Q active firms, n new entrants and an exogenous exit rate λ. In equilibrium the exit flow of firms is multiplicative in n (Dixit and Pindyck, p.276):

$$\lambda \cdot Q = nF(x^*) \tag{16}$$

where x* depends on the statistics of uncertainty and both x* and Q are determined in equilibrium by the activation condition and the free entry condition. Then the number of new entrants' n is determined in equilibrium by the last equation. If we assume that instead of λ, n is exogenous, then the competitive Dixit and Pindyck general equilibrium model is equivalent to the multi-factor Markov model introduced in this section, at least from an estimation point of view. In our equilibrium model of heterogeneous agents and in the Dixit and Pindyck model of firm heterogeneity the exit rate is multiplicative in the number of agents n. If the number of agents n follows a Markovian process (as implied by the equilibrium) then taking the logarithm of Y_t, ($Y_t = \lambda Q$) the above specification implies that there is a unique Autoregressive Moving Average Process of order p, q[4] (ARMA(p,q)) specification for the dependent variable $y_t=\ln(Y_t)$. A rigorous proof of this result is given by Tong (1983). Having specified the ARMA process we may then solve for the parameters of the state variable X_t and the parameters of the population dynamics, consequently. The dimension of the ARMA process depends on the number of factors that determine the evolution of n; namely the exogenous factors in Vstay,Vexit. In our analysis, we shall assume four explanatory variables: namely the time charter rate, the operating costs, existing fleet and the capital recovery rate. Although the ARMA process could have been well specified beforehand (due to Wold's Theorem (Tong)) this derivation provides structural insight into the interpretation of the parameters as well as to where the volatility stems from and has an equilibrium interpretation in this setting.

After estimating several parameterizations we conclude to the specification of an ARMA(p =2,q = 4) with tci, crt, opi and fleet included in the regressors X_t. Under the ARMA(4, 4) specification, due to the representation theorem, all the exogenous variables should appear statistically insignificant, which is the case indeed. However, we choose to include them in the regressors and include a smaller number of lags than population factors, since this allows us to control for their impact on the scrapping process and test their significance. Results of the estimation of ARMA(p =2,q = 4) are displayed in Table 4.

The Log pseudo-likelihood is L = 86.51 and the cumulative periodogram white-noise test for the residuals has a Bartlett statistic B =0.4732 and does not reject for the 0.05 confidence level. The above specification is efficient, if the selection of the MA terms is correct, but inconsistent if the number of MA terms is different than q = 4, or if the errors are non-linear. To account for a misspecification of the distribution of errors we proceed by estimating the model with the Double Two Stage Least Absolute Deviations Estimator (D2SLAD) as proposed in the seminal paper of Amemiya (1982). We use as instruments for the estimation the fifth and sixth lag of the dependent variable lnscrap and the results are displayed in Table 5. The coefficients of the exogenous variables appear to be in line with the ARMA estimation and the Hausman specification test is χ^2 (4) = 0.03 which strongly suggests we should not reject the null; namely the ARMA(2,4) specification. Finally, from a theoretical point of view it seems particularly interesting to examine the performance of the D2SLAD estimator for ARMA processes as well as the optimal IV moment conditions for this estimator. In this setting the Hausman specification test can provide us with a powerful tool for the selection of the model.

Table 4
ARMA(2,4)

lnscrap	**Coef.**	**Std. Err.**	**Z**	**p-0**
tci	-0.0000327	.0000104	-3.16	0.002
opi	.0002185	.0001097	1.99	0.046
crt	.0093303	.0096151	0.97	0.332
fleet	.0046969	.006889	0.68	0.495
cst	-1.556678	2.856471	-0.54	0.586
arL1	-.0818781	.0874084	-0.94	0.349
arL2	.8449426	.0844727	10.00	0.000
maL1	.3953347	.0959368	4.12	0.000
maL2	-.1644294	.1216234	-1.35	0.176
maL3	.0225011	.1015424	-0.22	0.825
maL4	-.1701627	.1197236	-1.42	0.155
sigma	.6212577	.1393909	4.46	0.000

Table 5
D2SLAD Amemiya (1982) Regression

lnscrap	**Coef.**	**Std. Err.**	**Z**	**p-0**
q1	-.731826	.293291	-.250	0.015
q2	1.184666	.2439871	4.86	0.000
tci	-.0000364	.0000205	-1.77	0.080
opi	.00023	.0000809	2.84	0.006
crt	.0120658	.0132641	0.91	0.366
fleet	.0058475	.0060778	0.96	0.339
cst	-2.253896	1.452131	-1.55	0.125
Pseudo R^2	0.4004			

Before concluding we estimate the model by using the classical Two Stage Least Squares (2SLS)[5] estimator (Hausman (1983)) with the fifth and sixth lag of the dependent variable as instruments for the first and second lag. Results are displayed in Table 6 (where Lag1 and Lag2 refer to the first two lags of the dependent variable) and all coefficients are in line with the previous estimates.

Table 6
2SLS AR(2) Regression

lnscrap	**Coef.**	**Std. Err.**	**Z**	**p-0**
Lag1	-.152339	.329644	-0.46	0.645
Lag2	.8784917	.2319875	3.79	0.000
tci	-.000023	.0000106	-2.17	0.033
opi	.0001688	.0000859	1.97	0.053
crt	.0073308	.0114263	0.64	0.523
fleet	.0052652	.0041309	1.27	0.206
cst	-2.139099	1.154969	-1.85	0.068
R^2=	.6244	Root MSE=	.72939	F(6,78)=15.21

In line with our previous argument, 2SLS is consistent, as long as the error term is uncorrelated with the instruments, namely the fifth and sixth lag, but inefficient if the model is indeed ARMA(2,4). This leaves space for a Hausman specification test that yields a value $\chi^2(4) = 2.35$ and slightly rejects the null. Overall, different estimation methods are supportive to the ARMA(2,4) specification. The ARMA(2,4) results suggest that the particular combination of lags is not a cause of endogeneity. We therefore perform Ordinary Least Squares estimation of the model and perform a Hausman test with the Instrumental Variable 2SLS estimator and the test is $\chi^2(2) = 2.36$ which slightly rejects the exogeneity hypothesis. Finally for the OLS estimation the R^2=0.6819 and the Mean Squared Error is Root MSE=0.656.

Having completed the specification and estimation of our model of scrapped tonnage let us discuss the results. All coefficients of the exogenous variables X_t are in line with economic theory. The level of time charter rates has a negative effect on scrapping decisions, since higher rates provide less motivation for scrapping a vessel, whereas operating expenses have an adverse positive effect on scrapping decisions. Finally the total fleet appears to have no impact on scrapping dynamics.

V. CONCLUSIONS

In this section we have proposed structural models for the exit (scrapping) data in the tanker market industry. Besides providing a good fit to the data we have proposed models that are supportive to the following:

1) Under the existence of an organized second hand market for the assets (vessels), convergence of the expectations of heterogeneous agents and the existence of traded

contracts (spanning assets), heterogeneity has found to have no direct impact on the specification of the model. On the other hand, the evolution of the number of agents, considering scrapping decisions, has turned out to be critical for the specification of the model.

2) Operating costs appear statistically more significant than operating revenues for the exit decision. Furthermore, existing tonnage and pending orders appear to have no significant effect on the scrapping process, **which verifies the hypothesis that exit decisions in this industry are mainly not due to capital replacement.** This contradicts the earlier hypothesis of Koopmans and to the knowledge of the author this is among the first studies that provide microeconometric empirical evidence on the financial nature of the behavior of exit.

3) Models with less structure than partial equilibrium models (like the one derived in Dixit and Pindyck, Chapter 8) appear to have more explanatory power. Simple Markov factor models seem more flexible and sympathetic to exit dynamics, in this industry at least. However, all the proposed models have a Markovian representation and correspond to the existence of equilibrium. Count data and time series ARMA models provide a unique framework for analyzing decisions of entry and exit in applied economic problems and additional motivation for the employment of these models beyond the traditional applications of high frequency financial data.

ENDNOTES

1. I thank Dr. Arlie Sterling, President of Marsoft, and Kevin Hazel for providing the data.
2. The intensity determined by an agent with an exponential utility coincides with the intensity we derive in Appendix B by using a first order approximation. The exponential utility assumption, which might seem restrictive, may be replaced by convergence of expectations under rational learning and leads to the same specification.
3. In the Negative Binomial specification, the conditional variance is equal to the conditional mean times a factor greater than one. The Negative Binomial specification is discussed by Hausman, Hall and Griliches (1984).
4. $$y_t = \sum_{j=1}^{p} arL_j \cdot y_{t-j} + X'_t \cdot \beta + \sum_{k=0}^{q} maL_k \cdot \varepsilon_{t-k}, \quad \varepsilon_t \sim N(0, \sigma^2) \tag{17}$$
5. $\beta_{2SLS} = (X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z'y)$
6. It seems interesting to investigate if we can derive this specification in a utility based structural framework.
7. $(x)^{+} = \max(0, x)$

APPENDIX A

Let X be a random variable with Poisson distribution; namely:

$$X \sim P(X = x \mid \lambda) = \exp(-\lambda)\frac{\lambda^x}{x!} \tag{18}$$

The associated Moment Generating Function of the Poisson distribution is:

$$M_x(t) = \exp(\lambda(\exp(t) - 1)) \tag{19}$$

If n is an integer then $Y = \sum_{j=1}^{n} X_j$, where $X_j \sim P(\lambda)$, in.i.d.

Then the Moment Generating Function of Y is the following:

$$M_y(t) = E\exp(-t \sum_{j=1}^{n} X_j) = \prod_{\xi=1}^{n} \exp(\lambda(\exp(t) - 1)) = \exp(\lambda n(\exp(t) - 1)) \tag{20}$$

This Moment Generating Function implies that $Y \sim P(\lambda \cdot n)$. The above derivation can be generalized for the case where X_j are in.d. with $X_j \sim P(\lambda_j)$.

Then, following the same argument:

$$Y = \sum_{j=1}^{n} X_j \sim P(\sum_{j=1}^{n} \lambda_j) \tag{21}$$

Now let $B_j, j = 1,..,n$ denote in.i.d. Bernoulli random variables with $B_j \sim B(p)$. Then the Moment Generating Function of Y is:

$$\begin{aligned} M_y(t) &= E\exp(-t\sum_{j=1}^{n} B_j) = E\prod_{j=1}^{n} \exp(-tB_j) = E_N E_{Y|N} \exp\prod_{j=1}^{n} \exp(-tB_j) \mid N \\ &= E_N((1-p) + p\exp(t))^N \end{aligned} \tag{22}$$

Now set $\beta = (1-p) + p \cdot \exp(t)$ and:

$$E_N\beta^N = \sum_{k=0}^{\infty} \beta^k \lambda^k \frac{\exp(-\lambda)}{k!} = \sum_{k=0}^{\infty} \beta^k \lambda^k \frac{\exp(-\lambda\beta)}{k!} \exp(\lambda\beta)\exp(-\lambda) = \exp(\lambda(\beta - 1)) \tag{23}$$

Combining the previous two results we get the following specification for the Moment Generating Function:

$$M_y(t) = \exp(\lambda \cdot p \cdot (\exp(t) - 1)) \tag{24}$$

This implies that $Y \sim P(\lambda \cdot p)$.

APPENDIX B

In this section we demonstrate that the exponential utility assumption, which is essential for the derived models, may be replaced by assuming convergence of expectations. We assume n heterogeneous agents, who consider exiting the market. Each of them determines his optimal threshold of exit, as well as his own value function V_{jt}, where j stands for the jth agent and t stands for time. Each agent determines his value function from choosing optimally to remain in the market and operate the vessel, which will be denoted $V_{jt,stay}$ hereafter and his associated value function from optimally deciding to exit the market as $V_{jt,exit}$. We assume that each agent assigns a Markovian specification to the process, which implies that all value functions are determined by the variables at time t and the parameters of the process. We furthermore assume that the number of vessels each agent scraps follows a Poisson process with intensity λ_{jt} and the probability of no exit for each agent is [6]:

$$\pi_{jt,0-exit} = \exp(-\lambda_{jt}) \tag{25}$$

By assuming that the risk premia offered by shippers (observed by the owners, but not by the econometrician) or scrappers belong to the family of Extreme type errors, the above probability is also equal to:

$$\exp(-\lambda_{jt}) = \frac{\exp(V_{jt,stay})}{\exp(V_{jt,stay}) + \exp(V_{jt,exit})} \tag{26}$$

This specification implies that the probability of zero exit (or the probability to remain in the market) is a monotonic function of $V_{jt,stay}$; the corresponding value derived from market presence. Solving for the intensity λ_{jt} we get the following equation:

$$\lambda_{jt} = \ln(\exp(V_{jt,exit}) + \exp(V_{jt,stay})) - \ln(\exp(V_{jt,stay})) \tag{27}$$

Hereafter we supress the time index t and set: $z_j = V_{j,exit} - V_{j,stay}$; then the first order Taylor expansion for λ_j has the following form:

$$\lambda_j = \ln 2 + \frac{\exp(z_j)}{1 + \exp(z_j)} \cdot z_j \tag{28}$$

or:

$$\lambda_j = \ln 2 + \pi_{exit,j} \cdot z_j \Rightarrow \lambda_j = \ln 2 + \pi_{exit,j} \cdot V_{j,exit} + \pi_{stay,j} \cdot V_{j,stay} - V_{j,stay} \tag{29}$$

Now we observe that the expected value of operating or exiting this market is:

$$E_j(V) = \pi_{exit,j} \cdot V_{j,exit} + \pi_{stay,j} \cdot V_{j,stay} \tag{30}$$

Plugging into our previous equation we get the following specification for λ_j:

$$\lambda_j = \ln 2 + \pi_{exit,j} \cdot z_j \Rightarrow \lambda_j = \ln 2 + E_j[V] - V_{j,stay} \tag{31}$$

The following specification of the intensity is valid as long as $\lambda_j \geq 0$, which implies that the specification for the aggregate intensity λ is the following[7]:

$$\lambda = \ln 2 \cdot n + (\sum_{j=1,n} \ln 2 + E_j[V] - V_{j,stay})^+ \cdot (\sum_{j=1,n} E_j[V] - V_{j,stay}) \tag{32}$$

Taking a closer look we observe that $E_j[V]$ corresponds to the value of owning a second hand vessel for a **risk neutral investor**. Since an organized market exists for second hand vessels we assume that under risk neutrality $E_j[V]$ is the same for all agents and it corresponds to the market or second hand price of the vessel. It includes the value of operating the vessel and the option to wait and therefore exceeds $V_{j,stay}$, which takes care of the non-negativity restriction on the intensity specification. Our final assumption is the following:

$$p\lim \sum_{j=1}^{n} \frac{V_{j,stay}}{n} = \hat{V}_{stay} \tag{33}$$

which implies that heterogeneous beliefs converge to an average, which is invariant to the number of agents, namely to the value an agent would assign if he had perfect knowledge of the process. This implies that heterogeneous beliefs for the value function converge to the unique value function that corresponds to a rational expectation equilibrium. Convergence to a competitive equilibrium requires convergence of beliefs to the equilibrium process. Persistent deviations from equilibrium would either result in breaks in the intensity, or under the prism of complete markets, in arbitrage opportunities. The intuition behind this assumption is that otherwise some players could persistently outperform the market, by taking advantage of the inability of other agents to converge towards the true process. The above specification implies that to first order at least, the mean conditioned on the number of agents is multiplicative in the number of agents n and coincides with the specification of the model with exponential utility. This implies that the source of extra volatility needed is either due to the remaining terms of the approximation or the dynamics of the population n. The basic claim of our model is that heterogeneous beliefs do not distort the multiplicative mean specification, at least in the long run. The only extra source of volatility is now due to the evolution of agents.

One more implication from the above specification is that there could be breaks in the intensity of the Poisson process of aggregate scrapping data, arising from disequilibrium and heterogeneity. We obtain the following specification for the intensity, for these values that result in an indicator function equal to one:

$$\lambda = \ln 2 \cdot n + (\sum_{j=1,n} \ln 2 + E_j[V] - V_{j,stay})^+ \cdot (\sum_{j=1,n} E_j[V] - V_{j,stay}) = (\ln 2 + (E[\overline{V}] - \hat{V}_{stay}))n \tag{34}$$

Table B1

Model	PQMLE (Boom)	PQMLE (Recession)
scr1	-.0834 (.0781)	.0287 (.0385)
scr2	-.0280 (.0864)	.0983 (.0269)
tci	-.000141 (.000055)	-.0000971 (.000028)
opi	.0002791 (.000258)	.0003061 (.000059)
crt	-.6250 (.2461)	.0036 (.0046)
cons	8.037 (4.417)	.1969 (.3411)
R^2	.0892	.2497

In a "bullish" market the indicator function is "to first order" equal to zero, since the value of remaining in the market is high enough to offset any expected value added by the option to scrap. This is a rather simplistic approach, which however provides us with a good motivation for considering a Poisson process with structural changes, as a result of the interaction of heterogeneous agents.

Before concluding this section we present the results from estimating the Poisson model with a structural break in the intensity of the Process. It is well known that if the separation function (the function that assigns each observation to a specific regime) is known in advance, then we may simply estimate the model by separating the data. If the separating function is unknown or endogenous, then estimation can become complicated, especially given the small number of observations available in our case.

We assume that the separation variable is crt which is the Marshalian rate of return and corresponds to an estimate of the capital replacement time. We estimate the model for crt < 10 (boom period) and for crt > 10 (recession period). We then perform a generalized Chow test. Results are displayed in T ableB1. The generalized Chow test is a special case of the Hausman specification test. Under the null that coefficients are equal in both regimes, we obtain efficient and consistent estimators, when imposing the restriction of equality, but inconsistency under the alternative, under which our restriction is invalid. If we estimate the model taking into account the two regimes, then our estimation is consistent, but inefficient under the null. Thus, the generalized Chow test is a special case of the Hausman specification test and in our case it is a $\chi^2(6) = 22.78$, which clearly rejects the equality of coefficients in both regimes. One major limitation of this test is that it is very sensitive to the a priori knowledge of the separation function.

The results are displayed in Table B1. We perform estimation for several other selection rules and by inspecting the residuals it becomes apparent that very little has been gained by assuming a structural break, whereas the main inefficiencies of the specification are still present. This finding provides additional motivation to our key conclusions and is supportive for the homogenous Poisson specification.

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