Modern Economy, 2021, 12, 1296-1319
https://www.scirp.org/journal/me
ISSN Online: 2152-7261
ISSN Print: 2152-7245

Scale Economies: An Economic Blessing? Should We Build Still Larger Ships?

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How to cite this paper: Goulielmos, A. M. (2021). Scale Economies: An Economic Blessing? Should We Build Still Larger Ships? *Modern Economy, 12,* 1296-1319.
https://doi.org/10.4236/me.2021.128068

Received: July 10, 2021
Accepted: August 28, 2021
Published: August 31, 2021

Abstract

We represented shipping production using the Cobb-Douglas function: $Q = A \times C^a \times L^b$, which relates: 1) Capital, Labor and Production. 2) Indicates: Embodied technical progress; 3) the shares in production of Capital and Labor, and 4) the Scale Economies! We consciously digressed from "constant returns to scale", and selected $a + b > 1$ for shipping industry and $A = 1.07$ due only to the higher speed of the vessel. We dealt also with the Marshallian artificial distinction of the economic periods in short and long. This we had to do it as the scale *economies* were related to long run, when capital (ships) is changeable. In shipping, we have the wrong idea that Capital and Labor quantities are fixed, and so isoquant lines are right angles. However, we accepted this as a working assumption, and also, we adopted complementarity between Capital and Labor. We showed also that shipping companies can be **always** in the long run! Shipping microeconomics is incomplete. The equilibrium of: 1) the vessel and 2) the shipping firm in the short and long run is missing. We attempted to provide these, as well industry's equilibrium. Moreover, we showed the equilibrium… outside the equilibrium during a shipping depression and boom, when demand is either shorter or higher than **optimal**. We emphasized the technical efficiency of the vessels at shipbuilding stage, and then we introduced the iso-cost lines. Mathematically and diagrammatically, we identified the scale economies in maritime industry, where seaborne trade is the King. The typical bulk carrier from 34,000 average size in 1981 reached 81,284 dwt by 2011, judging by ships on order (2.4 times larger)! This paper revealed, however, that the Global financial Crisis in end-2008 **curtailed** scale economies! Two numerical examples used proved scale economies in maritime industry: the cost of building a 30,000 ship fell from \$867 per dwt to \$347 (for a 170,000 dwt), and *the long run average total cost* fell from \$191 to \$74… Also, for a 75,000-dwt tanker the *long run aver-*

age total cost fell from \$13.08 to \$6.72, for a ship 3 times larger. We found out also that ports "sabotage" scale economies in shipping as when the size of a tanker increased by 3 times, the port cost increased by 4 times! Our last warning was, however, that scale economies are a good thing, but they depend on the parcel size, and the other factors presented in the text, and in a final analysis they depend on appropriate, each time, *individual* demand (per vessel)! So, we may say to shipowners: build larger ships, if demand is there.

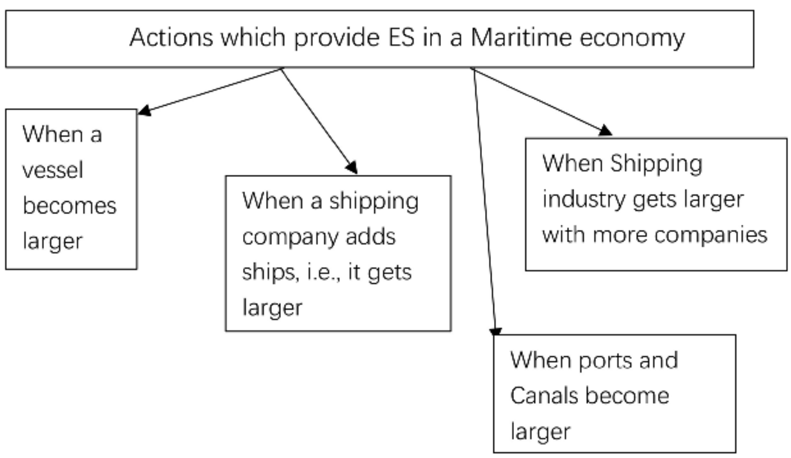
Keywords

Cobb-Douglas Production Function, Short and Long-Run Periods, Supplementary Analysis to Shipping Microeconomics, Evidence of Scale Economies in Shipping

1. Introduction

All along the establishment of economics, economists distinguished 3 types of returns to scale: constant, increasing and decreasing. Despite the fact that "increasing returns to scale" (Goulielmos, 2018a) are more interesting, economists for political reasons, stuck in the "constant returns to scale". While traditional economists tried to accommodate returns to scale even since the time of Marshall (Pearce, 1992: p. 122) able contemporary economists discovered the "economies of scope[1]" (Besanko et al., 2013: p. 63).

In shipping, we have 2 criteria of scale for companies: 1) the **number of ships** a company manages at a time, and 2) the **number of tons** of cargoes -liquid or dry which these ships can carry at about 95% of their dwt. This means that in shipping, ES can be recognized in 4 occasions: if a **vessel** gets **larger,** if a **company** gets **larger,** if the **industry** gets **larger, and if ports** become larger! (Graph 1)



Graph 1. Actions which provide ES in a maritime economy. Source: author.

[1]Savings which come from the increase in the **variety** (range) of goods, and/or services produced, unknown before 1990s.

As shown, the larger the size of a vessel or of a company, the higher the opportunity to gain scale economies. The larger the industry, meaning having more companies and vessels than hitherto, the more possible is to offer it a proper infrastructure. Ports and Canals are in fact partners and most scale economies in ships depend on Ports and Canals.

From the above criteria of size, the main is the *number of tons* (*dw*) *a company manages*. This indicates company's *carrying capacity*, meaning the *production capacity* of vessels per voyage. This also reflects the availability of capital embodied in ships as the only and most important factor for their size and for its higher contribution in value vis-à-vis labor (crew). This is why shipping industry is called **"capital-intensive"** or the ratio $Ct/Lt > 0$ {1} in production (capital/labor ratio) (perhaps 5 to 1.5).

However, the production of ships is not static, as it does not take place in a specific location, as in other industries, but production places are determined by the tons of cargo that they have to be **carried over, from** *origin* to *destination*[2]. As a result, the ship production is both dynamic, subject to many factors, given that a number of independent firms contribute, or prevent, or create costs, and also may "steal" time from ship's efficient and effective production! The ship manager has to manage and co-ordinate at least 5 - 10 other companies to complete effectively and efficiently vessel's production[3]!

Apparently, **time**[4] is a very strong factor of production in shipping (Goulielmos, 2018a), expressed in one objective *of all companies*: *achieve* "*a minimum off-hire time*[5] *by company's vessels*". This is *the maritime operational **efficiency***!

The production of ships, however, is even more complicated than in other companies. Ship's production is determined by the *distances that have to be covered*, depending also on the speed of the particular vessel and on the time spent in ports. Moreover, as a ship loads and unloads cargo in ports, and crosses Canals, port *efficiency* and *effectiveness*, as well posts' condition (congestion; ice; black-outs; rain, strikes etc.), affect the production of ships in *time* and *cost*. Ships when in ports *do not produce*, but they perform the **"delivery"** (of cargo within an agreed time).

Both ships and ports, as well canals[6], have increased their efficiency over time-though Ports and Canals are followers in the sense that they make their work as faster[7] as it can be, under normal circumstances, but **following** shipping developments. This can be recognized in what economists mean by ***external***

[2]Covering a number of sea miles of 1855.2 meters length.

[3]Ports, Canals, Sea (weather, waves, winds, currents, depths, swells, tides etc.), bunker suppliers, tug owners, agents, charterers, suppliers, clubs/insurance companies, crew, marine accidents, ship-repairs, dry dockers, pirates, terrorists, thieves, crew unions, coastal police (PSC), port authorities, pollution and safety guards, etc. all play a role in shipping production!

[4]Though excluded by economists in a "two-variables" environment!

[5]Meaning the time when a ship moves without being paid.

[6]Suez Canal is famous for its impact on shipping in its 1956 short and 1967 long closures, and in 2021, with the giant containership ("Ever Given"), which blocked the canal's passage!

[7]This means a number of changes like: proper sea depth, suitable length of quays, right loading/unloading equipment, computerization of things (!) for the least port time, etc.

scale economies and *embodied technical progress* in *ports* and *canals*!

The value embodied in the cargo carried by ships may induce the owner of cargo to calculate the interest[8] for the time the ship is crossing the sea and the time spent in port, till cargo can be bought to customers, and his/her money invested-in cargo is recouped. So, owners of cargo care about the duration (and safety) of the voyage, and appreciate the faster process, especially by companies which own containerships.

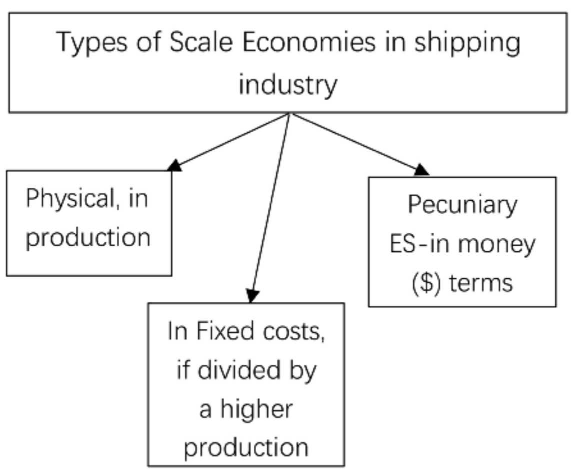
Moreover, the following distinction of ES (**Graph 2**), we believe, is very important.

As shown, scale economies are distinguished in money terms, and in physical terms. The analysis of scale economies in money terms is rather neglected though perhaps more or equally important, as we have done here. To most people scale economies coincide to the issue "when a fixed amount is divided over more units, like fixed cost."

Monetary scale economies come when large shipping companies negotiate with the suppliers of oil to obtain lower prices (discounts in annual contracts). Efforts can also be paid with shipbuilders, agents, ship-repairers, suppliers of goods, and spare parts, of lubricants, of paints, of engines, with dry-dockers, etc. to get discounts.

A shipping company, as mentioned, is capital-intensive, and as a result **its fixed cost** is higher in the form of *depreciation*, *administration cost* and *yield/profit sought after*, etc. *Fixed cost* is the one paid *independently of the level of production*, and is subject to reductions by spreading it over a larger amount of units produced (in the form of a rectangular hyperbola). As argued elsewhere, fixed costs are a **strategic variable**, which cannot be managed in the short run after ships have been built or bought etc. (Goulielmos, 2021a).

As argued (Goulielmos, 2021a) a shipping company has to apply a **strategy** right from its establishment in having a portfolio of ships' vintages in the **middle**



Graph 2. Types of scale economies in shipping industry. Source: author.

[8]Oil and dry cargoes are of low value per ton, but in large quantities may arrive at serious $m amounts.

of the age pyramid, as lower vintages have **higher** operating costs and higher vintages have **higher** depreciation and yield amounts (=fixed cost)!

2. Paper's Contribution

This paper tried to show, quantitatively, the existence of maritime technical progress, and if possible, to measure it in quantitative and in money terms. The tool was the famous Cobb-Douglas production function. First, we determined the value of $\alpha + \beta > 1$ (increasing returns to scale) somehow intuitively and then we estimated A, i.e., the coefficient of technical progress, at 7%, while keeping Capital and sea Labor constant. The technical progress embodied in ships in money terms was reflected in lower freight rates by 8.2% less p.a. (1945-2021) due to competition! Additionally, we completed the microeconomic theory of the maritime company. Moreover, scale economies proved with numerical and diagrammatic means.

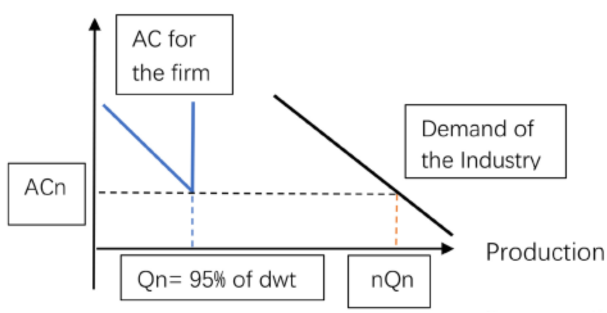
3. Aim and Organization of This Work

The paper aims at showing the impact that the **size** of the *capital* (ships) has on the production and cost of a shipping company. In fact, we aim at revealing the Scale **Economies** in shipping industry using data. This is the same, we believe, as to answer the questions: "Are shipping scale economies true? "And if so, how can a shipping firm achieve them?" Concurrently we will comment on the *artificial separation* of business life, made first by Marshall (1890), in **short** and **long** periods, showing that a shipping company, unlike its industry, *is **always** in the **long run**, if it so wants*!

Worth noting is that the paper moves within a competitive market (**Graph 3**).

As shown, the individual shipping company produces a *fraction* -made up by thousand-ton miles of the total production required by total demand, which is expressed in *billion* tons, and in equilibrium, AC should be equal to Price (MC = MR; equality of marginal cost to marginal revenue, and average cost). The AC curve indicates that a vessel cannot produce more than 95% of her capacity.

By **Graph 3** we do not mean that Supply is not influenced by an individual company (like the "Sanko Co of Japan" in 1980s: see Stopford, 2009, p. 126; the "Eletson") or by a group of companies (Oil companies in the past called seven sisters)!



Graph 3. A shipping company in a competitive market. Source: author.

The paper is organized in parts, after literature review. Part I dealt with Cobb-Douglas Production Function. Part II dealt with the short and long production periods. Part III dealt with completing the theory of shipping production, and showing firm's and industry's equilibria. Part IV dealt with the Scale Economies in Maritime Industry in practice. Part V provided an applied example of scale economies with data from tankers' chartering. Finally, we conclude.

4. Literature Review

Worth noting is how a methodology applied by Marshall (1890) which moreover was not wanted, as he stated in the determination of **prices** of goods, to become a **central tool** in building a **competitive advantage** in Business Economics! Marshall (1920) mentioned the term "long period", among other 3 ones, to indicate the time when a firm can make **adjustment** in its product *price* (Blaug, 1997: p. 682; 359-363).

Viner (1931) drew the long run average total cost (LR/ATC) curve of a firm, known as the *envelope*[9] of all short-run average total cost (SR/ATC) ones! This means that a firm **can** *easily* and *smoothly increase its scale*, and *by so doing* ***reduce*** *its long run average cost*! Reality, however, is somehow more **difficult**. Marshall's theory of the "short period" is by now very familiar, as most of it is found in modern textbooks and we will be brief on it.

Moreover, *short run* for a shipping company may cover a **short time** of its life a few… months. In fact, *short run* is a period, for a shipping company, we believe, when today is like yesterday, and tomorrow is like today. Everything we can, according to theory, is **only** to **produce** at t an amount ≥ or < than $t - 1$, or what we mean by "business as usual".

Long run, however, is the period during which whatever had to change for the better, it has been changed (our definition). Thus, some companies will stay in the short run for ever, and others, the champions, will march into long run, we believe. But as we have argued elsewhere, many economic statements *sound true*, but they are *deceptive.* One of them is the "scale economies", and the other is the *extreme* "division of labor" or *perfect specialization*.

Robinson (1965) stated the classical one of economists: in the "short-period, the *stock of equipment* is *given*" (p. 65), recognizing it as a *convenient theoretical abstraction* (p. 179). She also wrote that the "economies of the division of labor[10]" determine the *minimum* size of each type of a productive company (p. 69).

Of course, each entrepreneur, and a shipowner, is continually struggling to *enlarge* his/her business, and *new* firms are launched from time to time (Goulielmos, 2021b). Robinson (1965) argued that to increase the production (p. 336)

[9]The long-run average cost curve *envelops* the short-run average cost curves. Called also a planning curve showing the least cost of producing a given level of output.

[10]To allocate labor to the activity in which it produces most. A best use of skills. Labor is divided among tasks according to its comparative advantage. No one person carries-out all tasks. Known as *specialization*.

from, or with, a single plant, this has certain **limits**, due also to the "specialization of the equipment".

This last means that a firm is expected to concentrate its equipment (ships) to the production where it has a *natural* or *acquired* advantage… In shipping such advantage may come from the *quality* of crew, the quality of ships, or their special technical characteristics (e.g., double hull).

Such advantages, however, it may make company's life easier, but shipping business life (=demand) **allows and other companies to survive**[11], if the *homogeneity*[12] property of services exists. Market prices are determined on the basis of the cost of the **marginal producer** (having the higher cost), if his/her production is needed. This is an important observation explaining why ships with high total cost continue to carry cargoes...

Above, in shipping, we determined the minimum staff, and the *minimum size*, of a (Greek) shipping company, we believe (excluding containerships; cruising and passenger ships). The above structure is the absolute necessary structure to carry-out operations, chartering, supply, port attendance, crewing, insurance, technical attendance, repairs, maintenance, accounting and MGA etc. and other office obligations in a tramp shipping company.

Tarski (1979) tried to present scale economies in transportation in very bad English. He found that the transport cost of oil by tankers from Persian Gulf to Japan in 1967, per ton, was falling from 16 shillings to 8.5 as the ship increased from 160,000 dwt to 600,000!

Stopford (2009: p. 75) admitted that ES played a major part in keeping sea transport **costs low**. For Stopford (p. 223) the relationship between **cost** and ship **size** defines ES. The total cost covers: operations, voyage, capital, cargo handling and maintenance (periodic). This has to be divided by ship's dwt for one to arrive at average shipping cost.

Lorange (2009: p. 87-88) argued that a shipowner may have very **similar** assets, and it might pay to *standardize* his/her fleet. We may call it "the sister ships advantage". Examples are the "General Maritime", primarily owning Aframax and Suezmax tankers, i.e., almost similar designs, common spare parts, more standardized operations, common maintenance, etc. Also, "Seaspan" owning 23 identical (4250 TEU) containerships. Among Greeks, "Eletson Ltd Co" derived such *benefits* to the best of our knowledge.

[11]This reminded me of the **differential rent** obtained by the more fertile land at the time of Ricardo. In his theory, the **price** of an agricultural product is determined by the cost of the less fertile land, called "marginal land", which is brought into cultivation to **satisfy** demand. The more fertile land has a lower cost and so there will be a difference (a rent) vis-à-vis price. Thus, ships with higher cost required to satisfy demand will obtain a freight rate covering their average variable cost at least, which will be higher than that of the more efficient ships, which will get an extra revenue (a rent). Efficient ships are not necessarily the youngest ships (Goulielmos, 2021a), as mentioned.

[12]This means that charterers *believe* that the services of ships they are going to use are **identical**. This means that ship's age, her owner, maintenance, safety, security, etc. do not differentiate the nature of the service. In other words, there is one condition of perfect competition. The last decades, however, especially in tankers, charterers prefer ships under 15 years of age because they fear to have a marine accident. This has distorted perfect competition in shipping economics.

Besanko et al. (2013; chapter 2) argued[13] that few concepts in microeconomics are more fundamental to business strategy than … ES. By ES they mean the vehicle that one may use to obtain a *cost advantage* over its competitors!

This review has revealed a few important points. The first is that market allows companies with high average cost to be present in the market. The 2nd is that a shipping company is most of her life in the long run. The third is that the more scrapping is taking place, the more ships of larger sizes and lower ages, are replacing other ships, and the faster technical progress and scale economies emerge. The real pushing factor for technical progress is the new-buildings. Unfortunately, in 2021 we have the lowest level of such orders in the last 12 years!

The most valuable message of this review is that the lowest possible costs will determine firm's success, and this can be done… by scale economies. Maritime economists present economies of scale (Stopford, 2009: p. 436) as granted, and just note that tankers increased from 17,000 dwt in 1950 to a VLCC in 1966 and a ULCC in 1976. In 1968 an 80,000-dwt tanker had cost about 27s in the pound/per ton (Rotterdam-Kuwait), while a 200,000-tanker had cost of about 18s or 34% saving (Stopford, 2009: p. 436). We did not stop to warn, however, that big ships need big cargoes!

5. Part I: A rich Production Function

Scale Economies exist **if** a **reduction** of the **long run** ***average cost*** (Total Cost/Qt), of the products (or services) produced (=output), is achieved. This can be **done,** by an **increase** in company's *production*, *Qt*, ***due*** *to a* ***higher demand***[14], **requiring** a greater quantity *of* ***all*** *factors of production.*

Some inputs, as a result of the higher demand, and the additional time, stop to be ***fixed,*** *as hitherto* (*e.g., capital equipment*)*. ES* mean quantitative (physical) savings. This does not exclude savings due to human element, *par excellence pecuniary* savings (see below), or other savings or economies, of course (e.g., of learning, of density etc.). In fact, economists have introduced quite a number of *economies*[15] (this way… justifying their name)!

Scale reflects the quantities of all inputs used at one period in the **production** of a firm. ES are realizable, and do not occur automatically, like a "manna from heaven". They are an excellent **target** for companies. ES are distinguished in *internal* and *external*.

Economists, since long ago, were "jealous" of Physicists and of Mathematicians, because latter's sciences "allowed" them to be positive, precise, elegant and their theories could be subject to experiment! But economists must be prouder, we reckon, as their science is 1/2 based on Psychology (Goulielmos, 2018b, 2018c), and the other 1/2 on Economic Man's Free Will (Priesmeyer, 1992)!

[13]They characteristically wrote: "the bigger, the better".

[14]From the beginning, we put emphasis on the **prices** of **services** produced, because by examining the side of a maximum production first, and then of a lower long run average cost, we may assume that the **prices** of services **always permit** expansion to a higher scale!

[15]By 1990s we had → economies of: growth, learning and scale; after 1990s we had → economies of scope, and of density.

One tool of the mathematicians, which relates together 4 important economic concepts, Output, Capital, Labor and Technical Progress, is the "Cobb-Douglas production function". This was first used by Wicksell (1851-1926) in 1901, and discovered independently by Cobb & Douglas (1928). Here we will use a *generalized* version of it by assuming

$$b \neq 1 - \alpha \text{ or } \alpha + b > 1, \tag{1}$$

assuming **increasing returns to scale**. The returns to scale represent the rate at which Qt changes as the quantities of **all** inputs are varied.

Let a company's output, Qt (=production)[16], to be carried-out with the help of Capital, Ct and Labor Lt quantity:

$$Qt = AC^{\alpha} L^{b} \tag{2}$$

(an exponential equation), where α, b and A are constants (Eltis, 1966: p. 66), (Chiang & Wainwright, 2005: p. 386). In shipping industry, we expect, in the long run, the **labor quantity** to *fall* and the **capital quantity** to *increase*, in a ship newly built, for reasons explained below.

Example: let α = 1, and assume that the size of the vessel is doubled, from 60,000 to 120,000 dwt, meaning $2Ct$, and labor (crew) to decrease by 10%, from $1Lt$ to $0.90Lt$, and let b = 0.03. Then production Qt + 1 will be[17] 1.99 (rounded) times higher ... than before, assuming A = 1.

The constants α and b show the elasticity of production to Ct and Lt respectively, meaning the change in production due to a change in either Ct or Lt. They are called also *distribution parameters* meaning that they indicate the shares in the production of Ct and Lt. This is why certain economists prefer $a + b = 1$.

Did we **arbitrarily** assume that A is equal to 1? Yes… A in shipping must be higher than 1, given that between a vessel of 60,000 dwt and 120,000 dwt, *embodied technical progress* must have caused at least **one** knot higher speed! Thus

$$A = 1.07\ . \tag{3}$$

Then

$$Qt + 1 = 2.13Qt \tag{4}$$

(rounded) (=increasing returns to scale)!

Varian (1990: p. 302-303) argued that A measures the **scale** of production -roughly speaking when Ct = 1 and Lt = 1. This means

$$Qt + 1 = A \times Qt \times Ct^{\alpha} \times Lt^{b} \text{ and } Qt + 1 = A \times Qt\ , \tag{5}$$

given Ct = 1 and Lt = 1. A may be considered as an **efficiency parameter** and indicator of the **state of technology** (Chiang & Wainwright, 2005).

Absolute important, we reckon, was to select $\alpha + b$ -in shipping- > 1! We selected also b = 0.03, assuming that a decrease in labor quantity (crew numbers)

[16]It can be shown that an optimal production is a function of the price of the product, i.e., wages and the price of capital (Chiang & Wainwright, 2005: p. 337-338).

[17]$Qt = A \times 2^{1} \times 0.90^{0.03} = A \times 2 \times 0.9968441 = 1.9936883$ and $A = 1.07$, $Qt = 2.133246481$, going from 14 knots to 15 knots.

in essence leaves ship's production intact[18]! This ($a + b > 1$) is a **very important selection, as mentioned,** as by this, we have **excluded**: all *linearly homogeneous* equations, *constant returns to scale* as well *Euler's theorem*!

In shipping, there were no attempts to estimate a or b. In estimates applied to US manufacturing, a found equal to 0.25 (1899-1922 = 24 years), 0.10 and 0.50 (Douglas, 1948) and b equal to 0.75. Technical progress can be detected by function (3), meaning that technical progress is "embodied". Cobb and Douglas (1928: p. 155) set $A = 1.01$. But they did not name A as a technical progress coefficient, but as standing for: "the quantitative effects of any force for which one has no quantitative data" and thus A stands as a catch-of-all the effects of such forces".

Here we assumed A as showing the influence of speed only; but there exist and other factors like cranes, the ship's design, etc., which increase the efficiency (time and production) of the vessel. But we have to exclude from A the distance effect, which has nothing to do with technology.

Moreover, Cobb and Douglas (1928) adopted constant returns to scale etc. by having: $a + b = 1/4 + 3/4 = 1$. To catch technical progress perhaps one needs long data (the sail-steam-oil transition e.g., took place gradually over certain centuries). In another paper we will try to estimate A for maritime economy.

6. Part II: Short and Long Runs

We saw that ES were related **only** to long-run! Because, in the **short run**, a firm is **assumed** not to change its ***fixed*** factors of production, apparently **capital**, which coincides with the criterion of **scale** in shipping, and needs time to be produced than to produce.

To put the above more correctly, and more generally: *short run* is the (calendar) time[19] in which one factor of production, i.e., capital, cannot change (assumed fixed). The short-run distinction is also due to Marshall[20] (1920) (Chap. V) (p. 313-5), (1890: 1st edition), who introduced it for the first time.

In shipping, *theoretically*, the number of ships in a firm in the **short run cannot change**, but not even labor (number of crew). This also means that neither the **size** of existing ships can change (by modification). The Capital/labor ratio is fixed, *after the ship has been constructed*. But (her production), i.e., the number of voyages per year, the sea distances covered, as well the speed of steaming applied, the bunkers consumed, the periodic maintenance carried-out, etc., all these costs and factors can vary in the short run.

[18]Neoclassical economists, and Solow, are fond of $a + b = 1$. This is so because then Euler's theorem holds determining the "distribution of income" mathematically and not politically! The value of production is shared by Ct and Lt in accordance with their **value of marginal products**, which somebody may consider fair.

[19]Marshall avoided to define short run in calendar time and what he meant was "operational" time.

[20]Marshall wrote about "*time periods*", but he considered them as no inventions of **Nature**. He wrote: "Nature has drawn no such lines in the economic conditions of actual life" (p. 314). And these periods were not wanted! The time of adaptation to changing circumstances of producers and of consumers (Blaug, 1997: p. 354), Marshall meant by time periods.

Short run is the time one lives, and makes business! In the long run, as Keynes said, everybody is dead! Long-run is the time for company's vision to be realized. Short run is the time to survive, so that to be round tomorrow. Short run is the bridge to long run. Shipping depressions destroy this bridge, and the passage cannot be made.

Short run is the fight time, and there, death can suddenly occur and a company has to be prepared to pass to long run, where time restrictions, limitations, obstacles, excuses etc. are removed… A short run after a short run brings a company to the long run. Life is a continuous function (in mathematical language), but business life **is not**, if company's serious diseases are not cured in time. A successful short run allows a company to pass to long run, the same way life during one day leads to next day and all these today days lead to next year (i.e., to long run).

7. Part III: Our Theory of Shipping Production; Firms' and Industry's Equilibria

Economists have to cooperate, we reckon, with shipping Production Engineers, and shipbuilding mechanical engineers, because maritime economists require shipping production to be *technically efficient* first, so that to apply, next, economic conditions (i.e., the prices of inputs)!

Mathematics provided a production function in which, as we showed, two-usual suspects: *variables*/inputs, Capital *Ct* and labor *Lt*, are used to produce a third variable: output, *Qt*, (all variables > 0).

Shipbuilders may say that a single combination of *Ct* and *Lt* can be combined in a number of different ways, to produce different levels of *Qt*. Production function, however, pre-supposes *technical efficiency*, as mentioned. *Qt* is then the *maximum obtainable one from every possible Ct and Lt combination*. So, technical efficiency has to be prior, so that to apply the economic principles thereafter.

One advantage of the newly built ships is their *technical efficiency*, *which relates them to a particular route*. For used ships is no guarantee that they will serve the same route as that designed by their first owner. In practice, shipbuilders have standardized the types of ships for obvious reasons in 5 - 6 sizes (in **Table 1**) and taking into account canals' dimensions, port sea drafts as well distances and the nature of cargo, the price of oil, speed's level, fuel consumption, etc.

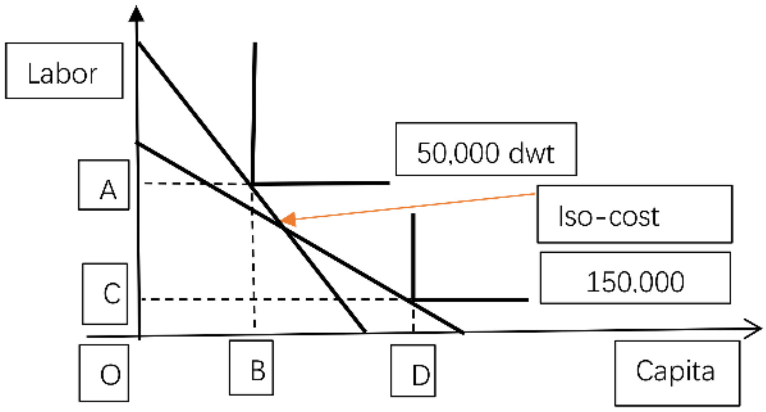
Shipping is a peculiar industry, because non-shipping economists consider the right-angle isoquants (**Graph 4**), as an **extreme** case, in which one factor cannot be substituted by the other (labor for capital, and vice versa). So, in shipping the 2 factors of production supposed to be are used in **fixed** proportions (Bilas, 1967: p. 59). Then the "elasticity of technical substitution" is **zero**. Prior to this, the price of capital[21] and the price of labor will determine the proportions in which these factors will be used (expressed by iso-cost lines).

[21]Primarily determined by the price of steel for ship building.

Table 1. Sizes of different ships, building prices, operation cost and total cost per dwt, 2005.

Size (dwt)	Price ($ m end-2005 new building)/per dwt	Ops. Cost m$ per year	Ops. Cost, $ per dwt	Total cost p.a. per dwt -**long run average cost**
30,000	$26m/$867/dwt	1.2	40.0	$191
47,000	31/$660	1.4	30.0	$143
68,000	36/$529	1.8	26.5	$120
170,000	59/$347	2.0	11.8	$74

Source: author; data selected from Stopford (2009: p. 224).



Graph 4. Long run equilibrium of a shipping company having 2 scales. Source: author.

In order to establish a shipping firm, we need to build, or buy, 1 at least, vessel, and, as shown, let this be of a size of 50,000 dwt initially. To do this, one needs OA units of Labor and OB units of Capital, given the technology prevailing in the shipbuilding industry at the time of her order. Isoquants show what the shipping firm ***wishes*** to do, given its production function. The iso-cost lines[22] tell us what a shipping company ***can*** **do,** by having the funds to buy the vessels, hire the crew etc. Using 2nd hand vessels, one introduces no new technical progress. But 2nd hand ships cannot be excluded from this investigation because they change the capital of a shipping company.

We also need 2 years, on average, for vessel's construction, depending on the phase of the shipping cycle. We also need an amount of $, say $30 m - $60 m, and $1.5m p.a. for the labor cost, shown by the iso-cost lines. An iso-cost line shows the fixed amount of money, which can pay the company to get the combination of 2 inputs. For the 2nd hand vessel, the time to obtain her may be 1 - 3 months, due to the existence of a well-organized 2nd hand market, as mentioned!

The right-angle lines are known as "*isoquants*" or "equal product curves" or "curves bringing equal quantity of product". These indicate a **complementary** relationship between *Ct* and *Lt*. This means that the combination of *Ct* and *Lt*,

[22] $S = aP_{C_t} + bP_{L_t}$ (6), where P_{Ct} is the price of one unit of capital and P_{Lt} is the price of 1 crew member on average, and *a* and *b* are the quantities of *Ct* and *Lt* used in production. (6) is the so-called **budget line**.

shown by them, provides a single production of 95% of 50,000 dwt or 150,000 dwt[23].

If a shipowner wants to achieve a higher production than 50,000 dwt, then another isoquant appears. In this second case, we have a higher size of the ship (3 times larger) and an increased amount of capital (OD) and a lower amount of labor (OC). The iso-cost line may be:

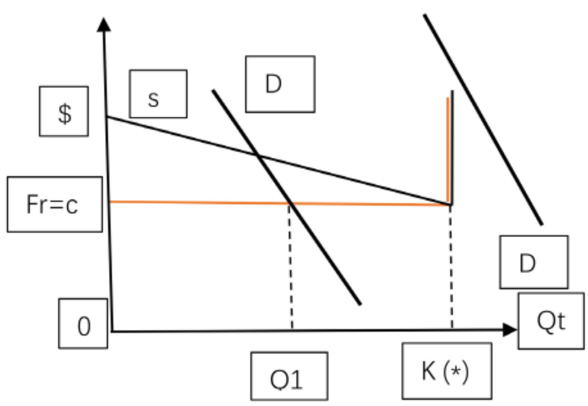
$$S = \text{OD} \times \$600 + \text{OC} \times \$75000\,. \tag{7}$$

There may be a low limit, we believe, of the quantity of labor, which is necessary[24], and thus we may say that labor, $Lt \geq 18$ persons, given the state of technology. The size of crew is determined by law, and it takes certain technological advances into account (e.g., an automatic engine room).

7.1. The Optimal Freight Rates during a Shipping Cycle

Assume that we have one plant (one ship), which has a fixed capacity (in dwt). Let K (*) be the maximum number of ton-miles that she can produce per period of time (=one voyage). The company runs also a fixed cost F, which varies over the units of production (average fixed cost). The marginal cost is constant at 0c (Graph 5). The equilibrium production is at K (*) (which is also optimal providing the largest $ value of the possible benefits in excess of costs (Train, 1991: p. 13). We drew also a MC curve, the s, the way we believe to be more correct.

We assume that the demand is higher at the upper phase of the shipping cycle (boom), Dp, and lower at the downward phase (depression), Do. The period for each demand is not equal, but the peak is 3/8 of the whole period and the off-peak is 5/8, over a cycle of 8 years (Stopford, 2009). As shown the freight rate



Graph 5. Two Marginal cost curves with a fixed capacity K. Source: inspired from those in Train (1991: p. 242).

[23]The dwt production is 5% less in the form of cargo carried, due to the weight that other inputs have (water, stores, bunkers etc.).

[24]This is an assumption at the present state of shipbuilding technology. Research for ships with zero crew is going-on. **Automation** is the technical progress that has reduced labor on board, so far. Labor on board is reduced due to its cost, but also due to its difficult availability in numbers and quality required. In shipping, technical progress is subject to safety of the ship and of cargo and crew. Given, however, that new capital cost covers the 50% of total annual cost, labor cost is only 15% of total operating cost out of say $10m p.a.

Fr is equal to oc (=MC). The demand is satisfied by the existing ship capacity. However, OQ1 < than K (*) and so firm loses money. This is the result of a depression and of a low-capacity utilization. Interesting is that Cobb-Douglas (1928: p. 152) distinguished production according to times of prosperity and depressions.

The way we drew the MC curve, s, assumes that MC is falling as capacity utilization increases towards 100%. This MC curve permits for a ship to undertake a voyage at say 60% of her dwt, given Fr. We assume, however, that the company at OQ1 < 60%K (*) will refuse to undertake the unprofitable production (voyage).

When demand is Dp, capacity cannot cover demand, and so freight rate may be raised by demand and supply. The ship earns revenues **in excess** of her variable cost (not shown). Given that the 2 periods, we defined them unequal, the excess revenue will be lower than the loss in non-peak phase. To break-even we have to bring-in fixed cost as well. During low demand the capacity is wasted and the ship may be removed from the market (laid-up), and in the long run replaced by a smaller vessel. The reverse is also true.

7.2. Reality Differs from Theory!

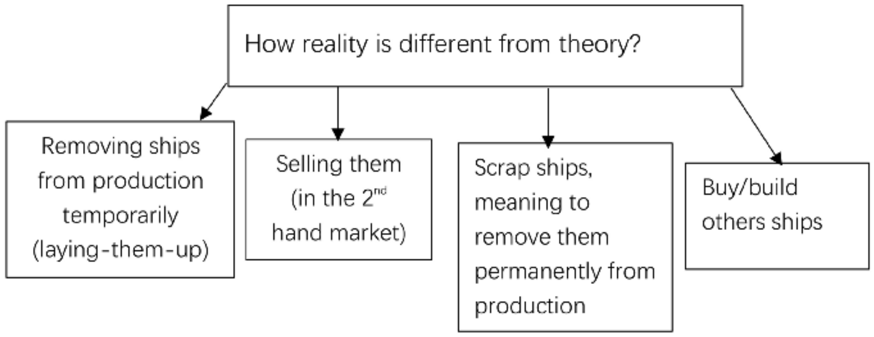
Worth noting is that a shipping firm, despite theory, can **change** in practice its fixed capital, if its management wishes, in short time (**Graph 6**). This means that *either shipping short run is very* ***short*** *or a shipping company is always in the* ***long run***!

What, however, we could not **find** in modern maritime economic textbooks, is a short run (**Graph 7**) equilibrium of a ***shipping*** **firm**! Suppose a shipping firm owns 1 ship (1 plant), producing OQ1 ton miles at a freight rate OP1, during 1 voyage, at full capacity utilization.

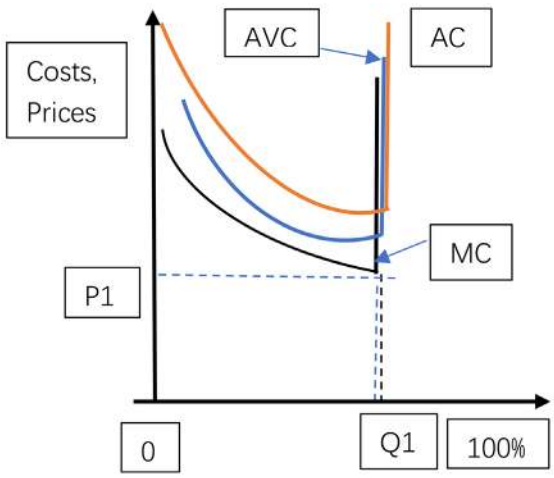
As shown, the vessel is chartered for 1 voyage of OQ1 thousand-ton miles at a freight rate OP1, at full capacity utilization, 100%. When the vessel is full, no further "production" is possible, and SR(AC) is at a minimum and vertical, and SR(MC) curve is vertical too as well AVC. The Marginal, and Average total costs and variable ones, are falling as cargo loaded increases till vessel is full. The cost per ton-mile (ship's another average cost in operations) also falls as vessel loads-up to her load line, and distance increases.

If the capacity utilization is not full, or over a certain %, the vessel will have losses, and she will not undertake the charter, we believe, as mentioned. If LR(AC) (**Graph 9**) < SR(AC), **it will pay** the firm to buy/build a larger vessel! Shipping is an industry of *increasing returns to scale*, or decreasing costs, (assuming fixed factor *prices* of labor and capital according to theory). According to Varian (1990: p. 351) the short run average cost curves must be **tangent** to the long run average cost curve. It is apparent that LRAC < SRAC.

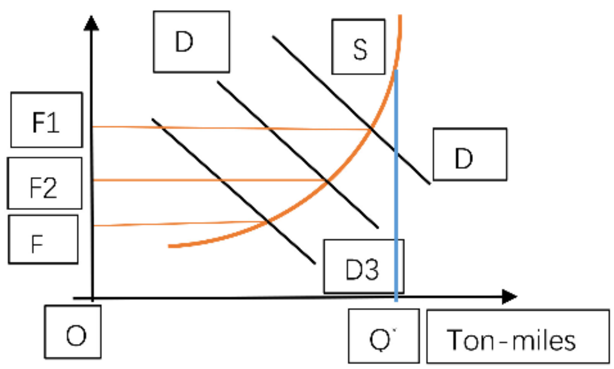
The short run equilibrium of the (shipping) **industry** is rather an **easy task** (Stopford, 2009: p. 165) (**Graph 8**).



Graph 6. How reality is different from theory? Source: author.



Graph 7. A shipping company in equilibrium in the **short run** producing OQ1 per 1 voyage at freight rater OP1. Source: author.



Graph 8. Short-run equilibrium of shipping industry. Source: author.

As shown, in the *short run*, the **supply** of ships becomes vertical at Q^*, which is the maximum world fleet size, together with a maximum demand for ton miles D1 (ships × distances, given speed and port time). Any additions to fleet needs time, of about 2 years on average, depending on the phase of the shipping cycle. If demand for ships increases, (in the short run), from D3 to D1, this will result to increases in freight rates, OF3 to OF1 (Graph 8). This is the short run equilibrium of the shipping **industry**.

We may follow now economic theory again and apply it to maritime microeconomics, presenting the short-run and the long run average cost Curves together (**Graph 9**). The company's fleet comes in 3 different sizes: small, medium and large. Once the shipping firm commits itself to a production facility of a particular size, it can change output only by varying the quantity of inputs other than ship's size/number of ships (capital) in the short run. For each ship size we drew an associated short run average cost function (SRAC).

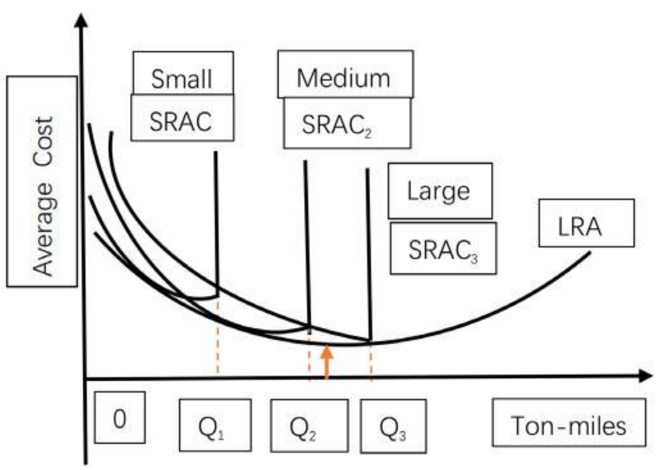
We have two options: 1) to connect the *tangent* points of each shipping SRACs curves, Q1-3, with the LRAC curve, and draw the shipping long run average cost. 2) To connect the **low** points of SRAC Q1-3, and draw the LRAC curve. The LRAC cost is falling as the size of production increases by increasing all inputs due to scale economies. Microeconomists argue that it is better-off to produce at the **tangency** point, where the per unit costs are lower par excellence, due to scale economies, (shown by the red arrow as there is the optimum scale of the ship!

Stopford (2009: p. 166) dealt with shipping long run cost curves drawing the supply and demand in long-term *adjustments*, between 1980 and 1992.

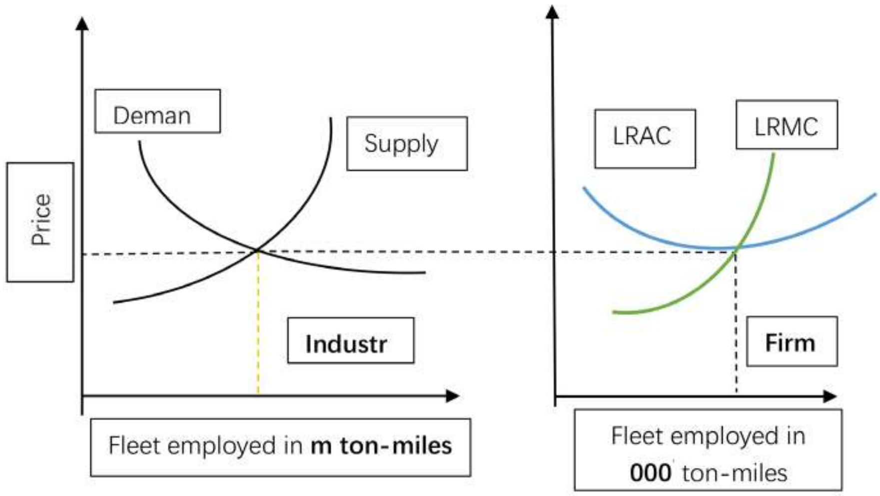
The freight rate is determined in the long-run by the Supply of ship space and the demand for it, given distances and average speed (**Graph 10**). The supply and demand are the King and the Queen in maritime markets, which together determine the freight rate (the price of shipping services). **Graph 10** is self-understood.

8. Part IV: The Real Scale Economies in Maritime Industry

The history of shipping economics provides valuable lessons, though history may be not repeated, as many say (Goulielmos, 2009)! The low freight rates (prices of shipping services) *prohibit* the building of ships. Prices (freight rates) must allow the owner to recoup his/her capital and the shipbuilder to make a profit. So, *technical progress* **depends** on the **level of freight rates expected** to be **obtained** by the **newly-built ships**.



Graph 9. Short run equilibrium of a shipping company in 3 scales. Source: author.



Graph 10. Equilibrium of shipping industry and of the firm in the long-run. Source: author.

Ships are destined to serve the *world seaborne trade* (demand). The seaborne trade under normal circumstances increases, as shown (Figure 1).

As shown, the seaborne trade increased 1.5 times since 1982, in 23 years. This is the proxy demand for ships, and its volume is expressed in *billion* tons. Important is to take into account the distances involved, and the time spent in ports and crossing canals, to estimate correctly the seaborne demand. If we take as a yardstick a ship of a handy size of 25,000 dwt, she increased in size 2 times from 25,000 dwt in 1970 to 35,000 in 1985 and 50,000 in 2007! This is due to the increased *parcel size* to begin with.

Graph 11 shows the 5 main factors which determine the size of a vessel and thus maritime scale economies.

Though ports *care for providing* suitable water depths for vessels of an increasing draft, they may delay this process, which is very expensive and perhaps repeated[25]. The distances are a factor that needs much attention. They may increase, meaning higher demand for the same trade, but they can diminish, if new supplies crop up in more near places vis-à-vis consumption centers. Certain times, suppliers of a higher quality of a raw material have emerged (e.g., iron ore from Australia to Japan vis-à-vis from Brazil).

Sometimes canals were closed making distances… longer. Demand may be excessive also if ships are stuck in ports *waiting* for loading or unloading (congestion). Certain costs run by the vessel, are **size related,** like most port expenses. If vessel's distance is short and the vessel is large, then port expenses are a heavier burden per year. So, **larger vessels** seek for **longer distances** and **fewer port calls**.

Important is also the *parcel size*, meaning the unit load, which differs from cargo to cargo, and is determined by the maximum size of each order placed by the importers at one time. This is influenced by the phase of the shipping cycle

[25]Ports where rivers may flow into them, bringing materials, they have to dig sea bottom frequently.

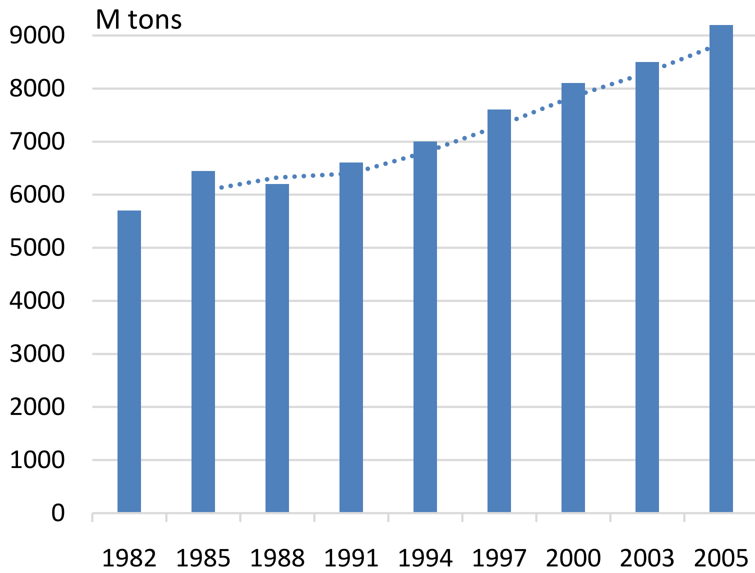
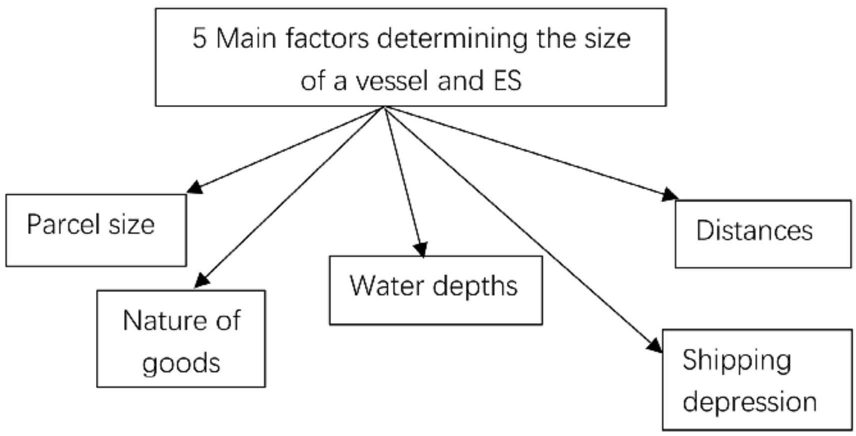


Figure 1. Seaborne Trade, 1982-2005. Source: data from Stopford, 2009: p. 719.



Graph 11. 5 Main factors determining the size of a vessel and ES. Source: author.

and the maximum storage capacity of the importers, the time they need to transform the unit load of raw material into ready products. The parcel size also depends on the size of importers as the larger ones will import larger quantities every time and reap economies of scale. Oil, iron ore, grain, coal, fertilizers, etc. and especially all dry cargoes and liquid cargoes are transported in large quantities in bulk (unpacked).

The average bulk carrier increased further in size between 1981 and 2006 from 34,000 dwt to 58,000 or 1.7 times (Figure 2).

Future scale economies are indicated by ships **on order**. Figure 3 shows this trend, where the bulk carrier size started from 64,214 dwt in Dec. 2000 and reached the 81,284 in Dec. 2011, or 1.27 times larger, and since 1981 2.4 times larger. Economies of scale reduced since 2009 *due to global financial crisis* in end 2008! In dwt terms Figure 4 shows ships on order (tons) since 2000 till 2011 and Figure 5 shows the number of ships on order between 2000 and 2011.

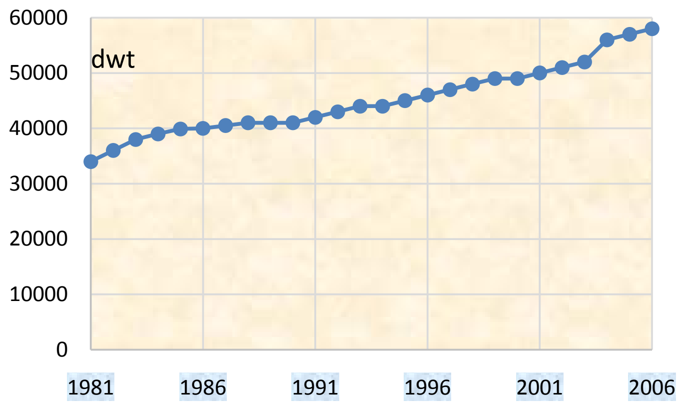


Figure 2. Average bulk carrier size trend, 1981-2006. Source: author; data from Stopford (2009: p. 76).

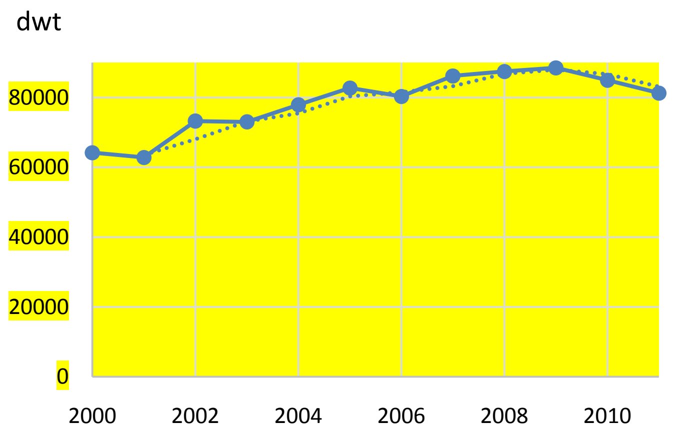


Figure 3. Bulk carrier fleet on order, 2000-2011: average size. Source: Author; data from Branch & Robarts (2014: p. 57).

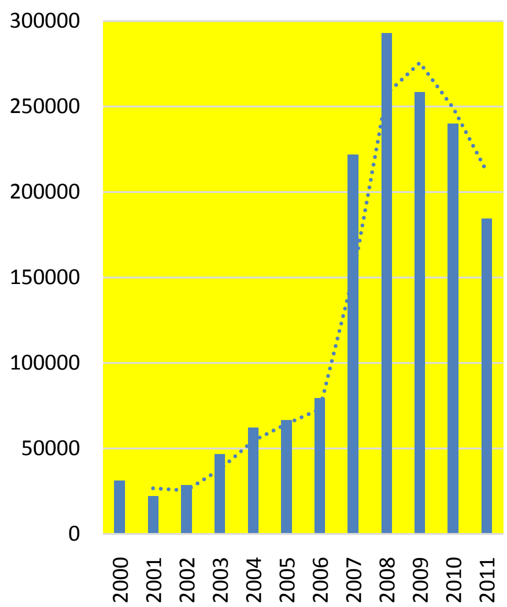


Figure 4. Size of Tonnage of the bulk carriers on order, 2000-2011. Source: as in previous **Figure 3**.

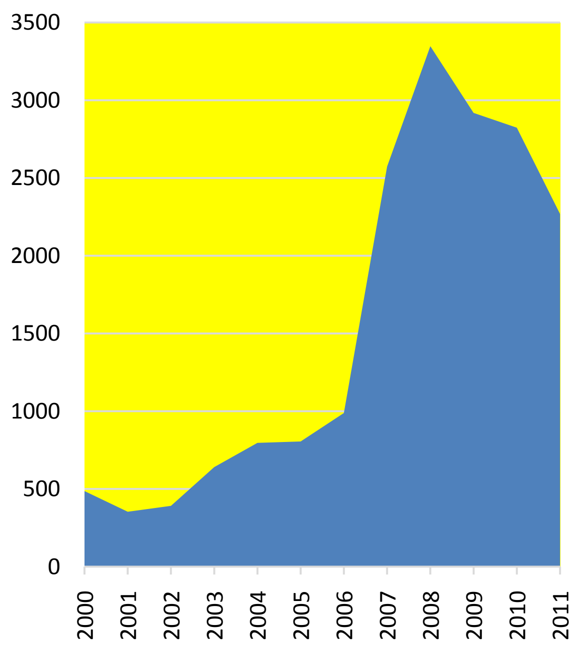


Figure 5. Number of bulk carriers on order, 2000-2011. Source: as in previous **Figure 3**.

As shown, tonnage and ships on order are influenced by the end-2008 shipping depression, and this affected adversely also the ships' average size and scale economies! Moreover, the number of ships on order, which are the **agents** of *embodied technical progress*, fell from a high of 3347 ships on order in 2008 (end) to 2,268 in Dec. 2011 (~32% less)!

Worth noting is that the costs of operation, for *voyage* and for *capital*, **do not follow** the size of the ship! Table 1 below summarizes certain facts related to the size of vessels.

As shown, scale economies are derived first from **building price**. A vessel almost 6 times larger, has a building cost per dwt 2.5 times lower than the 30,000 dwt one. Secondly, operating cost **per dwt** fell from $40 to $11.8. The total cost **per dwt** (long run average cost) fell from $191 to $74 going from 30,000 to 170,000 dwt. Given that we talk about new-buildings, *we are in the long run*. As the size of the vessel increased almost 6 times, the average total cost in the long run **fell** from $191 to $74 (2.6 times less) (=ES).

Bunker costs, and operation costs, however, **increase** by size in absolute terms, no doubt: a vessel of 30,000 dwt consumes 22t/day and pays $1.54m[26] p.a., against 39t/day of the 170,000 dwt one and $2.73m/year. The hire is $8.53m/year for the larger one against 4.02m for the smaller one. The smaller vessel (30,000 dwt) had almost 3 times higher cost per dwt p.a. (average cost) ($185 per dwt/year against $66/dwt/year for the 170,000 dwt).

Table 2 indicates the status quo of the trend of large ships in tankers and dry cargoes trades in 2007.

[26]At $200/ton. The vessel is 5.7 times larger and consumes 1.8 times more bunkers than the 30,000 dwt.

Table 2. The market share of the standardized sizes of vessels, tankers and dry cargoes, worldwide in 2007.

Type	Size dwt	Dwt m	Share %
Tankers			
VLCC	Over 200,000	147.0	**49**
Suezmax	120,000 - 199,999	54.2	18
Aframax	80,000 - 120,000	74.2	25
Panamax	60,000 - 80,000	23.0	8 = 100
Dry Cargoes			Share %
Capes	>100,000	125.7	**41**
Panamax	60,000 - 100,000	106.0	35
Handymax	40,000 - 60,000	74.1	24 = 100

Source: data from Stopford (2009).

As shown, the larger vessels in each category get the lion's share in seaborne trade transportation! The important precondition for this, however, is to maintain scale economies in maritime markets meaning to create the appropriate parcel sizes. This in turn means, when building new ships, to avoid the coming depressions!

9. Part V: Scale Economies through Tanker Chartering

The history of the "tanker freight rates" is interesting (Buckley, 2008: p. 165-170), "Intertanko" (1988). In 1969, the brokers in London and NY introduced the "Worldwide Tanker Nominal rate scale", known as "Worldscale" (in 1969). We will use this index in its **new** form to show the scale economies in tankers in real business life. The index in force will be used, which is applied in 1989 (01/01). This index is based on metric tons (1000 kgs) instead of long tons (1016 kgs) of the previous one.

Table 3 summarizes the impact of size on ship's cost.

As shown, the size of a tanker (75,000 dwt) performed a round trip from port A to port B and back, and had a cost of $13.08 per metric ton of oil carried (average cost). The annual cost made up by: port expenses $90,000 (9.6%), the cost of bunkers of $282,800 (30.15%) and the rest of all other costs of $565,200 (60.25%) (=$938,000 total).

Now, we increase **the size** of the above tanker to 225,000 dwt, or **3 times** exactly, and her **speed** by 1 knot. This will shorten the time at sea by 2.78 days, but the time in ports it will increase it by 4 additional days. The fuel consumption will increase[27] from 2800 tons to 5271! Moreover, Water = 100 t more; stores = 100 tons more; and by adding fuel, we have a dwt of 219,029 tons less (=production). This is a better % of space utilization of 97.346 for the larger ship and only 95.6%

[27]Fuel at sea 2218 t × 2; reserve 555 t; 200 t for other purpose; 80 t for ports. Price $101/ton = $532,371.

Table 3. Long-run average total cost for a tanker of 75,000 dwt and 225,000, 2008.

Ship's size, dwt	Speed (average service)	Fuel consumption/day in sea/in ports 24 hours, 380 cSt/other fuel; fuel cost	Distances, miles	Time (days)	Cargo carried	Freight
75,000	14.5 knots	55 mt/5 mt/100 mt; 2370 (\$1185 × 2); reserve 310; port 100; 20 in port = 2800 mt; \$282,800	15,000 for a round trip (7500 × 2)	Round trip: 47.1 (43.1 at sea; 4 in ports)	71,700 and Stores = 100t; Water = 400 Fuel = 2800 at \$101/t = 3300 tons	\$565,200; 47.1 days × \$12,000 = \$13.08/mt

Notes: 1) Port costs are \$15,000 in port A and \$75,000 in port B = \$90,000. 2) 96 hours laytime plus 12 hours; Panama Canal transit 24 hours; Suez Canal transit 30 hours. Source: data from Buckley (2008), p. 165-170.

for the smaller, meaning an additional income of 1.65%. The port costs increased to \$360,000 from \$90,000 (4 times)! So, the total costs of the larger ship amounted to \$1,472,211 consisting of: fuel \$532,371 (36.15%); 360,000 (24.45%) for port expenses and \$579,840 (39.4%) for all other costs.

Per dwt this last cost gives \$6.72, against \$13.08, or 51.4% less *long run average cost*. Economies of scale exist, as the size of the vessel increased 3 times, the long run average cost, **fell** by half (51.4%)!

The port cost, by the way, indicates that the size of the vessel is **punished** by the 4 times higher port cost, because port costs are based on ship's GRT or NRT (alternative measures of size used by ports) and rarely on dwt! This is not fair and the larger vessel should pay maximum \$270,000 port expenses, we reckon (according to her increased size in dwt). This is why, elsewhere, we argued that ports **obstruct** the scale economies in ships! This means that ports have to revise their price policy to **welcome** more larger ships.

Historically, ports based their price policy on the assumption that ships with larger capacity (GRT, NRT, dwt) obtain higher income, and so they have to pay a higher amount to ports, as ports were considered "partners"! If so, should ships in ballast pay a symbolic low amount as they carry no cargo?

10. Conclusion

We showed, mathematically, the scale economies in Shipping industry by using the Cobb-Douglas production function and assuming: $A = 1$, $a + b > 1$, $a = 1$ and $b = 0.03$, a double quantity of capital (twice a smaller vessel) and 10% less quantity of labor (crew; from 20 to 18 persons). We achieved almost 2 times additional production (in dwt) (+1.99).

Then we assumed a rise in vessels speed by 1 knot or from 14 to 15, meaning $A = 1.07$. So, the future production $Qt + 1$ increased also by $1.07 \times Qt$. This assumption of 7% *additional technical embodied progress* remains to be proved by an econometric model, but in another paper. Finally, production increased by 2.13 times indicating *increasing returns to scale*.

Marshall inherited to economists 2 economic periods among 4 called short and long. We showed that shipping companies can be most of their life in the **long run**, if they so wish. This implied specific strategies during short run for the company to stay alive, despite what Keynes said that in the long run everybody is dead. The truth is that one has to stay alive in the short run to be round in the long run!

We tried also to fill-in certain deficiencies in the maritime microeconomic theory, like: the equilibrium of the plant (the vessel); the short run and long run equilibria of a shipping company; the equilibrium of shipping industry and the equilibrium during a depression or during a boom. In most of these endeavors, we used right-angled isoquant curves.

Maritime scale economies proved to exist using data found in Stopford (2009) and tanker chartering (new "Worldscale"). A tanker, which increased by 3 times her size and obtained 1 knot higher speed, reduced the *long run average total cost* by half!

We also reached three important conclusions: 1) ports "sabotage" scale economies in ships by charging them excessively, where the size of the vessel trebled, the port cost increased 4 times. 2) Depressions cause scale economies in ships to be postponed. 3) Scale economies can be increased provided that parcel size also increases (the demand for larger ships has to be there to reap scale economies). In fact, with this third conclusion, we brought "coal to Newcastle", and "owls to Athens", as the same argued by Adam Smith in 1776, saying: that the "extent of the market determines the division of labor" (Besanko et al., 2013: pp. 70-71).

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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