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BENCHMARKING SHIPBUILDERS' TURNOVER OF MAIN ASSETS

Companies responsible for more than 50% of world ship production are compared and benchmarked in several criteria related to asset turnover. A historical productivity assessment is also presented for important players of the segment.

ABSTRACT

This paper presents an analysis of the historical and current asset turnover of several shipbuilding companies and regions, such being responsible for more than 50% of global production. Several turnover measures are used including, as inputs, main physical assets such as dock area, berth length and lifting capacity; and as outputs, CGT and the number of different ships produced. Data Envelopment Analysis is used to gauge the inputs and outputs of the companies in order to define their efficiency and identify the benchmarks in terms of asset usage. Results consolidated by region indicate that there are efficient companies producing in all of the regions studied: China, Europe, Japan and Korea.

KEYWORDS: shipbuilding; productivity; economics (shipbuilding), operations (general); asset turnover; data envelopment analysis; benchmarking.

1 INTRODUCTION

As in many countries in the world, the shipbuilding industry is today considered a high priority for the Brazilian Government. This priority has lead to several fronts of work in companies, the Government itself and universities aiming to facilitate the revitalization of the Brazilian shipbuilding industry.

This study is part of a broader effort directed at understanding the characteristics of the global shipbuilding sector and focuses on the supply side of the industry. As discussed further on in the paper, asset turnover has been one of the main drivers of the industry since 1998. While new dry-dock construction has been only marginal (less than 2%/year of dry-docks in place), turnover improvements have been growing by more than 10%/year. This evidence indicates the necessity to understand turnover and to benchmark the outstanding practices worldwide. The ultimate objective of such understanding has been to project the global shipbuilding capacity.

Turnover has several implications in shipbuilding performance, affecting financial results and productivity among other criteria. Shipbuilding literature (see Koenig et al., 2003, for instance) has customarily measured productivity as employee hours (MH) per ton for steel work, or employee hours per Compensated Gross Tonnage (CGT) for an entire vessel. Overall industry competitiveness, a comprehensive and comparative measure of productivity, is often reported as total cost (C) per CGT (including human labor, materials, outfitting, indirect cost, subcontractors and other costs that must be paid by revenues).

The first indicator (MH/CGT) is a powerful tool to compare technical and managerial capabilities in dealing with the operation, but which needs to be compared with the same operational leverage (automation) and outsourcing practices to be precise. A work force productivity comparison of shipbuilders with different levels of automation can be misleading since more automation usually means more productivity (fewer employee hours) but more depreciation costs. Thus, an automated shipyard may have exchanged the work force cost by the capital employed cost, and a smaller workforce in this context does not necessarily mean too much for the financial outcome or long-term success of the shipyard.

The second indicator (C/CGT) is a powerful tool to measure competitiveness in the market. Lower total cost means a greater margin with which to bargain with clients and greater survival chances in the long term.

In order to promptly compare operational productivity over different automation stages or outsourcing practices, this study introduces indicators that are related to asset turnover. The work does not intend to propose a substitute indicator for the traditional productivity indicators, but rather to propose an indicator that can be used along with MH/CGT and others when comparing productivities.

Since asset turnover has a direct impact on return on equity, it is expected that shipyards act to maximize it and, from this point of view, it is a good measure of the success in doing so. The return on equity is considered the most common ratio used to analyze the profitability of a business. The ratio can be deployed into three drivers: net profit margin, asset turnover and financial leverage. Profit margins relate to market conditions, financial leverage relates to availability of financial resources and asset turnover is the single pure operating driver of the return of equity. See Burns et al. (2008) and Mello-e-Souza and Awasthi (2009) for a more detailed discussion on the importance of asset turnover on overall business performance.

The study mapped more than 50% of global merchant shipbuilding capacity production and the main assets associated to it. The database was used to compare performance across companies and regions.

The first section of the paper defines asset turnover in the present context, shows how this indicator has been changing over time and discusses the trends. The second section presents a more comprehensive method for comparing asset turnover of the companies, and shows results by company and region. The last section discusses results and presents conclusions.

2 ASSET TURNOVER IN SHIPBUILDING

2.1 Asset turnover definition used in the paper

In financial analysis, asset turnover is conventionally defined as the ratio of revenue or net sales to total assets (see Bodie et al. 2001, page 614, for instance).

In this paper, asset turnover is defined in physical rather than financial terms. This was done to allow for direct analysis of specific shipyard assets. The concept underlying asset turnover is "how efficiently an asset is used". In the end, the concept encompasses several characteristics but one of the main ones is how the company (a company can have one or more shipyards) is managed. The concept of turnover used consolidates several of the companies' management capabilities into a single measure. Thus, for instance:

- A shipyard that does not use adequate planning, scheduling and control systems will possibly have lower turnover;
- A company that has a strong pipeline of orders will possibly have a higher turnover;
- A shipyard that has made wrong investments in the past, or wrong demand estimates, acquiring inadequate equipment or capacity, may possibly show a lower turnover;
- The shipyard that does not use the plenitude of its assets will show a lower turnover.

More specifically, the turnover of an asset *a* $(a = 1,2,\ldots,A)$ in company *c* $(c = 1,2,\ldots,C)$, η_{ac}, will be defined as

$$\eta_{ac} = \frac{p_c}{q_{ac}}$$

where p_c is the annual production of the company *c* and q_{ac} is the measure of capacity of asset *a* in company *c*. For the sake of simplicity, annual production will be given in CGT and q_a will be computed according to the asset under consideration. Three assets were analyzed in the study: dock area (m^2), berth length (m) and lifting capacity (t). Dock area and berth length are the sum of all dock areas and berth lengths of the shipyard, respectively. Slipways are computed in the dry-dock number. Lifting capacity is computed as the sum of the maximum lifting capacity of all the cranes in place. A 100t crane does not necessarily do twice the job that a 50t one does, but the maximum lifting weight is an indicator of its capacity when cargoes can be as heavy as ship blocks. Although the three assets are among the most important in a shipyard, the reader is referred to Storch et al. (1995, chapters IV and V) for a detailed description of other assets and processes used in shipyards.

2.2 Importance of asset turnover

Since dry-dock, berths and lifting equipments are some of the dearest assets in a shipyard, the rates of their use is certainly related to their financial performance. Financially speaking, the return on a company's equity is proportional to its asset turnover and hence the indicator is (or should be) continually monitored as an important corporate performance driver.

It is important to note that asset turnover is just another way of measuring productivity, which has historically been mainly manpower productivity in the shipbuilding area. See for example Pires Jr. and Lamb (2008), Koenig et al. (2003), and Lamb and Hellesoy (2002). The trend in manpower levels has been showing a clear decline everywhere and the outcome is one of the proofs that, over time, the importance of the direct workforce has been decreasing in favor of other resources such as automated equipment and outsourcing.

On the other hand, wages are usually one of shipbuilding's most significant costs, therefore causing a great impact on operating margins which are also proportional to the return on equity.

Although manpower is not directly considered in asset turnover computation, it is done indirectly since it affects the use of assets. For example, a dry-dock with 400 workers will possibly generate more output than the same dry-dock with 100 workers. It is interesting to note that the introduction of more people in the shipyard may prompt the opposite effect to the traditional way of measuring productivity in the shipbuilding area, i.e. more people tends to lead to better use of assets, and better productivity in the sense used here, while the traditional rationale suggests that more people tends to lead to lower productivity.

The asset turnover as a measure of productivity can be misleading, since it does not embodies all the important aspects for the productivity of a company. The particular point of view used in the paper should be included in a broader view of the shipbuilders' overall management problem. As will be shown, several conclusions from the definition proposed can be observed in practice.

2.3 Sources of information and estimates

Two sources of information were the basis for the analysis. The main source of information concerning shipbuilders, production volume and characteristics is the version of the Lloyd's Register - Fairplay World Shipping Encyclopedia, issued in the first quarter of 2006 (includes production for 2006). Companies' and associations' websites, documents issued by the companies (financial statements, fact books, etc.) and private sources were the main sources of information regarding the assets. Given the large number of companies and website links assessed to build the assets database, details of links are not provided in the references of the paper. Interested readers may find the information simply by accessing the websites of the companies or contacting the first author.

The judgment and experience of the authors were used to complete minor missing information, e.g. the classification of some shipyards as being focused on repair work, given the absence of new deliveries and company information.

2.4 Historical dry-dock turnover of two shipbuilders

Two of the companies in the sample provided dock size information dating back to the 80's. Besides the good quality of the information, Hyundai Heavy Industries Co., Ltd. and Imabari Shipbuilding Corp. (which includes the Imabari, Marugame and Saijo shipyards) are the largest shipbuilding companies in terms of CGT in Korea and Japan, respectively.

Using the exact definition of the dry-dock sizes over time in both companies and the information on production, production/asset was identified for two decades. Figure 1 shows the dry-dock turnover of both companies during the period. Lines with markers indicate the turnover of the year, while the solid lines show the 3-year moving average.

Some conclusions can be drawn from the figure:

- Turnover growth: The turnovers of both companies have been growing steadily since the 80s.
- Although different in both companies, the turnover range follows the same pattern when one considers specific periods: between 3 and 5 CGT/m^2 in the 80's; between 4 and 9 CGT/m^2 in

the 90's; and between 6 and 12 CGT/m^2 from 2001 on.

- The consistency of evolution indicates a robust indicator for the two cases.

It is important to note that Imabari practically doubled its dry-dock area in 2000 when the Saijo shipyard started its operations. The rump up of this site and middle year start up possibly explain why turnover dropped in 2000. Hyundai had its last capacity increase in 1996 when dry-docks number 8 and number 9 started to operate.

2.5 Eight-year dry-dock turnover series of several shipbuilders

- The same analysis described in the previous section was carried out for 20 other companies. The 22 sample companies were responsible for more than 50% of worldwide shipbuilding CGTs in 2005. The consolidated turnover by region is presented in Figure 2.

The sample of companies is composed of the shipbuilding activities in the following countries and regions (regions for short):

- China: China Shipbuilding Industry Corp. (Wuchang Shipyard); Dalian Shipbuilding Industry Co., Ltd. (yards 1 and 2); Jiangnan Shipyard Group Co., Ltd.; Nangtong Cosco KHI Ship Engineering Co., Ltd.
- Europe: Aker Yards ASA (Aker Braila SA, Aker Finnyards (Helsink, Rauma, Turku), Aker Ostsee (Warnemunde, Wismar), Aker Promar, Aker Yards AS (Tulcea)); Fincantieri - Cantieri Navali Italiani S.p.A; Stocznia Gdynia S.A.
- Japan: Hitachi Zosen Corporation (Setoda shipyard); Imabari Shipbuilding Co., Ltd. (Imabari, Marugane and Saijo shipyards); Ishikawajima-Harima Heavy Industries Co., Ltd. (Kure and Yokohama shipyards); Kawasaki Shipbuilding Corporation; Koyo Dockyard Co., Ltd.; Mitsubishi Heavy Industries, Ltd. (Nagasaki and Shimonoseki shipyards); Mitsui Engineering & Shipbuilding Co.; Tsuneishi Corporation (Hiroshima, Kagawa and Cebu shipyards).
- Korea (South Korea): Daewoo Shipbuilding & Marine Engineering Co., Ltd. (only Okpo shipyard); Hanjin Heavy Industries & Construction Co., Ltd.; Hyundai Heavy Industries Co., Ltd.; Hyundai Mipo Dockyard Co., Ltd.; Hyundai Samho Heavy Industries Co., Ltd.; Samsung Heavy Industries Co., Ltd.; STX Shipbuilding Co., Ltd. (only Jinhae shipyard).

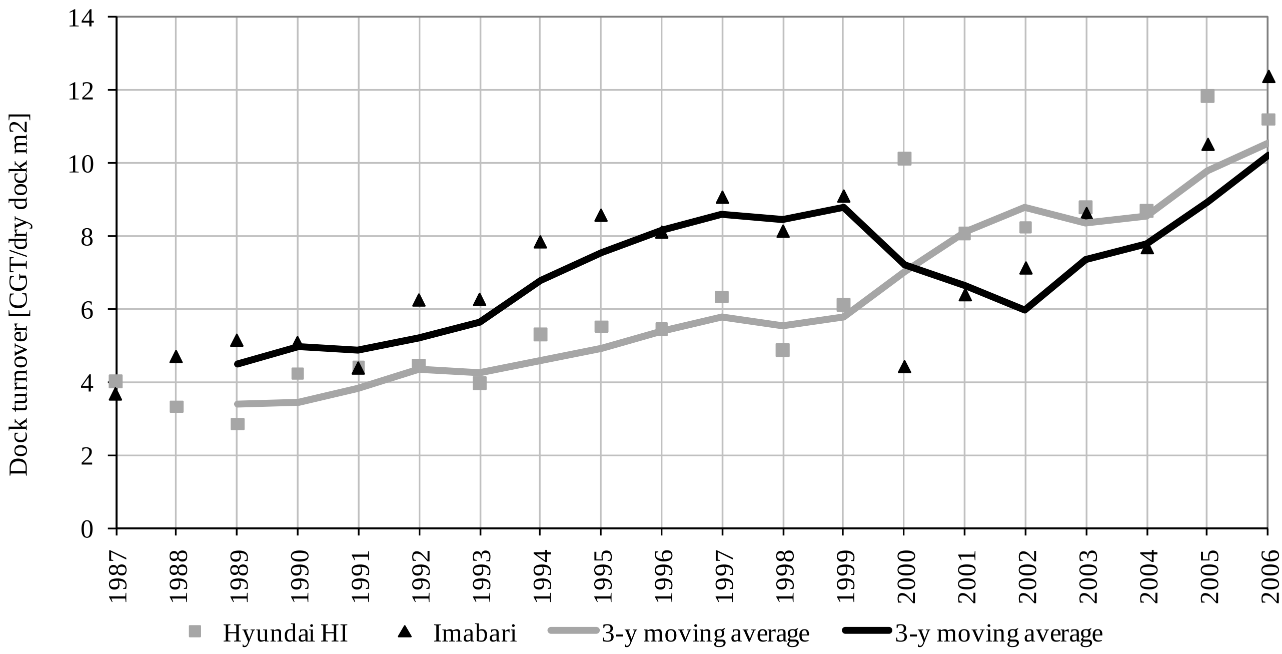

Figure 1: dry-dock turnover at the Imabari and HHI complexes over 20 years

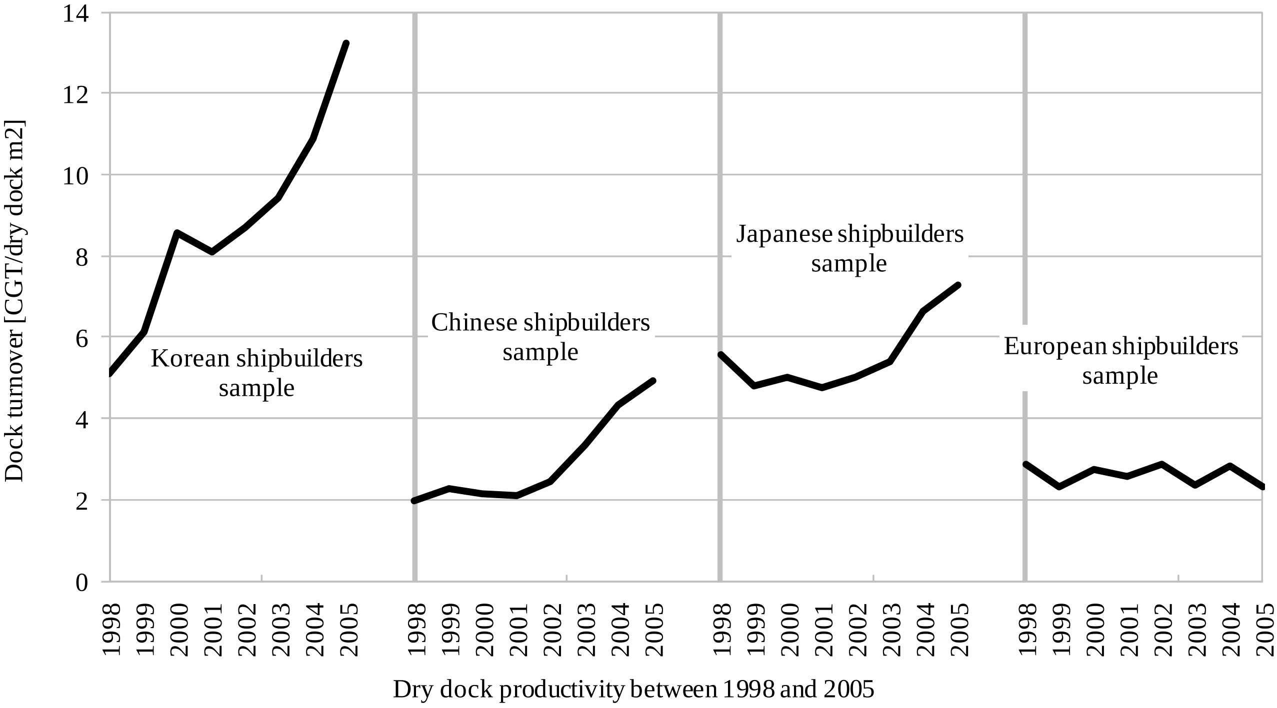

Figure 2: dry-dock turnover in different regions

Although it is not fair to classify dry-dock turnover of a region using the sample above, we will use terms such as "turnover of the region" for the sake of simplicity since the selected sample is not based on any statistical methodology. On the other hand, more than 50% of worldwide production, including the largest and most advanced companies, makes the sample clearly representative of shipbuilders' practices.

Productivity of asset a in region r $(r = 1,2,\ldots,R)$ is the weighted average of the turnover of all the companies belonging to the region, i.e.

$$\eta_{ar} = \sum_{c \in r} p_c \Big/ \sum_{c \in r} q_{ac}$$

The on-the-ground shipbuilding system used extensively in STX was excluded from the analysis and therefore its influence is not represented in the figures.

In general, higher turnover is found in Korean builders with 13 CGT/m². Turnover of Chinese shipbuilders in 2005 is comparable with Japanese and Korean turnover in 1998, around 5 CGT/m². European turnover is small compared to peers, hardly reaching 3 CGT/m².

Besides turnover levels, it is important to observe the impressive turnover growth in Korean shipbuilders when compared to shipbuilders elsewhere. The compound annual growth rate of the 3-year moving average is 11.4% in Korea, and 11.4%, 5.2% and 4.0% in China, Japan and Europe, respectively.

While past performance indicates the good work of Chinese and especially Korean shipbuilders, it also indicates a large room for improvement in Japan and Europe and, consequently, for more production without substantially increasing existing dry-dock areas. The argument is purely logical since Chinese companies have been announcing massive investments to increase shipbuilding infrastructure in coming years.

To assess the impact of Korean shipbuilders on global turnover, the sample was split into two sets: Korea and the rest of the world. The results are shown in Figure 3. Total CGTs produced and dry-dock areas are used as proxy of the set, and turnover is weighted by the size of the company. It is evident from the chart that the increase in aggregate worldwide turnover is driven mainly by the increase in Korean companies' turnover.

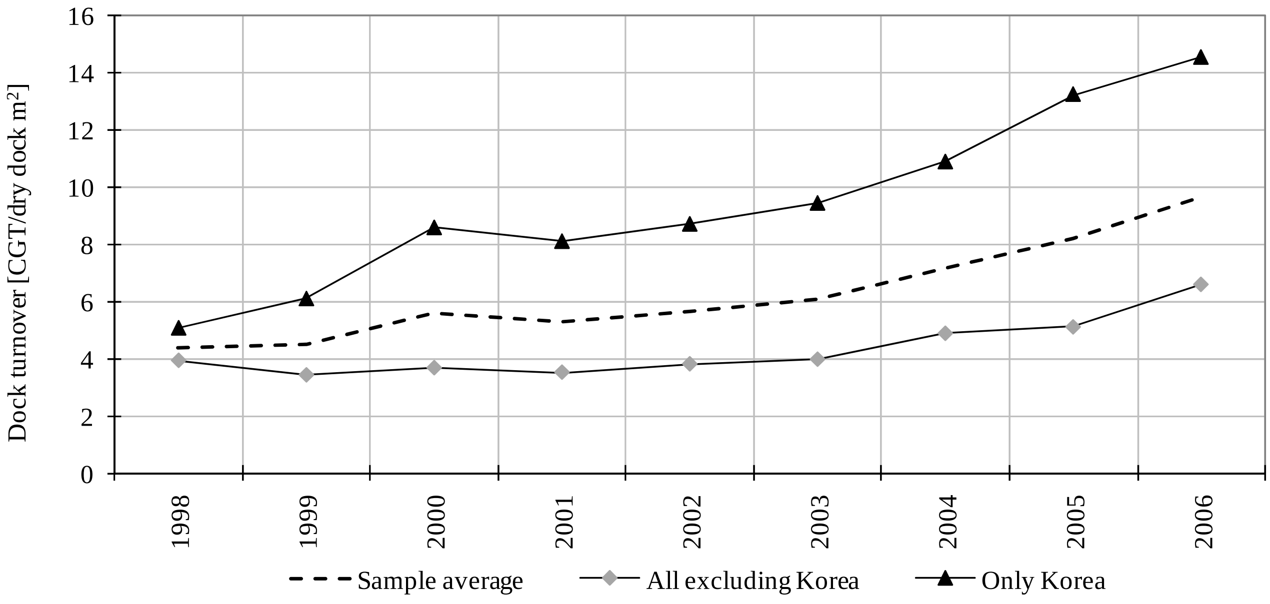

Figure 3: dry-dock turnover of Korean shipbuilders × others

2.6 Dry-dock turnover trends

This study does not attempt to identify the reasons why asset turnover has been changing. Gebhardt and Jarvis (2003) and Koenig et al. (2003) may be a good start since they offer an interesting discussion on several factors affecting improvements in productivity. However, the data allows the identification of historical patterns of the indicator. Several regression models could be used to fit the data, including exponential and linear models. Linear regression shows a good fit to the data, as can be seen in Figure 4. We have defined certain phases, based on the shape of the curve. In phase I, between 1977 and 1986, turnover growth was modest. On average, turnover grew by 0.15 CGT/m^2 per year (or 5.22%/year, on average). In the second phase, between 1987 and 2002, turnover grew by 0.23 CGT/m^2 per year (5.92%/year) and finally, from 2003 on, turnover has been growing by 1.18 CGT/m^2 per year (15.14%/year), or 5 times faster than in phase II and almost 8 times faster than in phase I.

It is likely that one of the main reasons for this impressive improvement is the result of unprecedented pressure due to demand. Improvements in turnover may be related to more and less efficient processes. Usually when resulting from pressure arising from a substantial backlog, it is not related to improvements in efficiency of those processes driven by cost reduction. Efficiency improvements usually last. If the high turnover of a recent period is mainly driven by demand pressure, the authors would expect a decline even in the outstanding shipyards as soon as demand slows down.

In terms of dry-dock turnover, Korean companies have been more successful than other producers studied. As time goes by, it is likely that the other producers will follow the Koreans and diminish the gap between them, even if the improvement is either demand or efficiency-driven. Although most of the discussion comparing successful and unsuccessful companies lies in technical issues, it is probable that the main reasons for the differences are associated with shipbuilding managerial capabilities and substantial investments in R&D. For example, it is well known that Hyundai HI, Samsung, and Daewoo maintain large R&D departments and give significant organizational importance to them.

There is no reason to believe that the recent upturn in dry-dock turnover will change substantially in the short term if the supply-demand balance does not change. Therefore, considering that most Korean shipyards have physical constraints to expand and new capacity requires years to be developed, any increase in supply will be aligned to an increase in turnover. If demand does not change substantially, the supply-demand balance will stay at the same level and, consequently, turnover will keep growing at the same recent rates. If order book size continues to be substantial, turnover will possibly continue growing at the phase III level. On the other hand, if order book size goes back to historical standards, it is possible that turnover will go back to the historical phase II rate. Phases II and III together represent 20 years of history, and there is no reason to believe that this long-term trend will change.

Improvements in productivity that have effectively resulted in additional capacity for output (i.e. not deriving from a stressed system) can be related to two kinds of improvements: those which are continuous and marginal, and those derived from new, breakthrough technologies. The second can be related to drivers such as on-the-ground production or to the fast growth of outsourcing off-site block construction.

It may be relevant to consider that the shipbuilding industry is usually heavily subsidized (mainly by indirect government actions in the depressed periods) and the decrease in capacity consequently takes a great deal of time to take place. When demand grows, there are several sub-utilized assets that can be turned on again and this would show a high increase in turnover, even though nothing new is happening on the factory floor.

If this was the only case, one should expect to see periods of depression in turnover rates in the series, an effect that was not observed during the period under analysis.

Another strong reason that indicates room for improvement in productivity is the turnover of some outstanding shipbuilders. Although average turnover growth rates have been very strong compared to historical trends, Table 1 indicates even stronger growth rates in some cases.

Table 1: dry-dock turnover growth rate in CGT/m^2/year

	Phase II (87-02)	Phase III (03-06)
Average shipbuilding company	0.23	1.18
Average Korean shipbuilding company	0.37	1.76
Two best performing Korean company	Not available	2.55

3 BENCHMARKING SHIPBUILDING TURNOVER

3.1 Data Envelopment Analysis

Currently, benchmarking analysis is one of the most widely accepted and used management tools: players are continually monitoring competitors to learn and replicate the best techniques. Benchmarking techniques can be traced to ancient times, but it was not until a seminal paper in the 70's that Charnes et al. (1978) proposed a formal (mathematical) method, denoted Data Envelopment Analysis (DEA), to accomplish the task.

Normally, a comparative analysis would use ratios to distinguish between poor and good performers. For instance, the ratio CGT/dry-dock area is a ratio that may indicate performance across companies and shipyards. But what if a company with poor performance in the dry-dock throughput has an outstanding performance in crane productivity? DEA tries to answer this kind of inquiry identifying the benchmarking Decision Making Unit (DMU, which is a company in our case) that is unequivocally the benchmark across all measurements under analysis.

More specifically, DEA considers that a given DMU has the following efficiency

$$Value\ of\ shipyards\ s'\ outputs \;/\; Value\ of\ shipyards\ s'\ inputs$$

Mathematically, each company c $(c = 1,2,...,C)$ has an output i, O_{ic}, where i represents the set of possible outputs $(i = 1,2,...,m)$. Accordingly, I_{ck} represents the value of input k $(k = 1,2,...,l)$ in shipyard c. Since the definition of the 'best performance' is subjective, DEA assumes that each company can define its own performance criterion, where a decision maker can assign specific weight to inputs according to his/her criteria. Consider that each company c can assign a weight w_i for output i and a weight v_k for an input k. In this case, efficiency can be defined as

$$e_c = \frac{\sum_{i=1}^{m} w_i O_{ci}}{\sum_{k=1}^{l} v_k I_{ck}}.$$

Once each company can define its weights, decision variables are w_i $(i = 1,2,...,m)$ and v_k $(k = 1,2,...,l)$ with w_i and v_k greater than 0. The objective of each shipyard is to maximize its efficiency. Arbitrarily considering that $\sum_{k=1}^{l} v_k I_{ck} = 1$, the objective of the shipyard becomes $\max \sum_{i=1}^{m} w_i O_{ci}$ subject to the condition that efficiency of the shipyard is smaller or equal to 1, that is, $\sum_{i=1}^{m} w_i O_{ci} - \sum_{k=1}^{l} v_k I_{ck} \le 0$ for $c = 1,2,...,C$. The formal and complete model is presented in the next section.

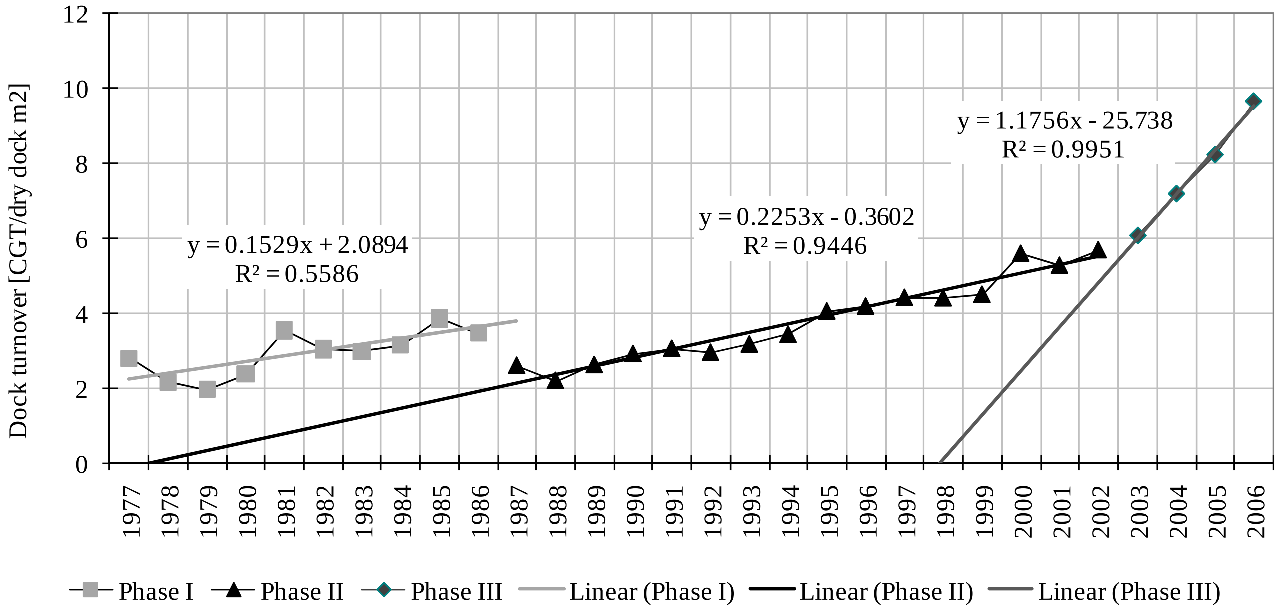

Figure 4: Dry-dock turnover of sample of shipbuilders

3.2 Input and output variables, and model

The definitions used before for main assets turnover are still valid. Outputs are measured in average CGT production and number of different ship types produced between 2000 and 2006. The types of ships considered are: Bulker, combination, container, dry cargo, miscellaneous, offshore, pass./ferry, reefer, roro, and tanker. The decision about the output took into account that for a given set of inputs, the greater the production and the number of different types of ships, the better.

The rationale for considering different ship types as an output measurement relies on the idea that a diversified production mix is more complex to manage and impacts negatively upon the ability to produce more. Also if a shipbuilder produces several ship types without losing productivity, it has a very important competitive advantage in the industry: production flexibility. Inputs are measured in dry-dock area, berth length and lifting capacity.

The whole model can be formulated as follows:

$$e_c = \max \sum_{i=1}^{m} w_i S_{ci}$$

Subject to:

$$\sum_{i=1}^{m} w_i O_{ci} - \sum_{k=1}^{l} v_k I_{ck} \leq 0 \text{ for } j = 1,2,\ldots,n$$

$$\sum_{k=1}^{l} v_k E_{ck} = 1$$

$$w_i \geq \varepsilon > 0 \text{ for } i = 1,2,\ldots,m$$

$$v_k \geq \varepsilon > 0 \text{ for } k = 1,2,\ldots,l$$

The problem is to identify weights w_i and v_k that maximize the efficiency of the company. Efficiency has to be smaller than 1 and weights have to be greater than 0. The model implemented in Microsoft Excel as a spreadsheet can be found in Colin (2007, pages 147-150).

3.3 Data set and results

To compute and compare the efficiency of the different companies, we used the database shown in Table 2. The "Region" column specifies where the headquarters and operations of the company are located. The "Company" column labels the company or shipyard under analysis. Part of the data relates to a specific shipyard and the balance to companies which contain two or more shipyards. Average CGT is the average production in CGT between 2000 and 2006. The number of different ship types produced between 2000 and 2006 in the company is presented in "# Ship Types". L, B and I represent dry-dock area, berth length and lifting capacity, respectively.

The units of the parameters are presented between brackets.

Results of the computation are present in Figure 5. Bars "Avg." indicate the arithmetic average of the efficiencies of the companies of the region. For example, a DEA efficiency of 51% of European company 12 indicates that, theoretically, it could provide the same production level and number of ship types with only about 51% of the resources it actually used. The Korean shipbuilding company 32 is an efficient company, i.e. its DEA efficiency is equal to 100%.

Table 2: outputs and inputs

Region	Company	Outputs Between 2000-2006		Inputs in 2006		
		Average CGT	# Ship Types	L [m²]	B [m]	I [t]
China	1	417,050	6	147,613	3,357	3,485
	2	90,768	4	22,920	1,200	305
	3	151,280	5	18,361	517	1,240
	4	20,388	3	19,021	316	720
	5	139,036	4	23,800	646	1,000
	6	119,959	5	69,363	1,980	867
	7	139,678	5	23,080	865	440
Europe	8	353,223	8	170,910	1,600	3,330
	9	23,809	2	15,395	1,300	790
	10	300,146	3	130,976	4,515	5,214
	11	119,856	4	14,725	325	450
	12	170,502	2	92,830	650	1,040
	13	158,663	6	16,846	189	1,556
	14	245,486	3	36,830	2,163	3,400
	15	91,194	3	89,473	1,552	1,532
Japan	16	119,737	4	13,073	332	1,170
	17	387,684	3	33,240	450	2,230
	18	170,709	2	37,380	800	3,335
	19	338,703	3	41,902	2,380	2,640
	20	352,097	3	103,788	563	1,330
	21	268,755	3	12,236	1,420	1,250
	22	170,252	2	22,420	550	1,170
	23	120,474	1	6,400	660	270
	24	382,667	6	27,037	395	2,225
	25	54,199	2	5,055	160	190
	26	222,063	2	22,800	514	1,034
	27	365,930	4	157,636	3,586	4,398
	28	448,789	4	150,332	3,504	3,269
Korea	29	2,269,353	8	240,125	5,000	4,960
	30	652,936	7	96,900	2,065	2,370
	31	712,161	3	78,500	2,200	2,040
	32	1,528,457	6	129,708	3,600	2,150
	33	476,226	3	45,956	1,141	1,780
	34	469,096	4	44,270	1,190	750
	35	28,246	2	2,071	397	193
	36	1,612,353	5	114,808	2,256	8,790
Total		13,691,927		2,277,780	54,338	72,913

As the reader can observe, all regions have efficient companies. Although Japan contains the largest number of efficient companies (5), on average, Korea is even better. The worst performing company in Korea has an efficiency of 69% while in Japan, only 22%.

Statistical tests of the results may improve the reliability of the comparisons. The test conducted uses the null hypothesis that two regions, i and *j*, have a difference in terms of DEA efficiency equal to Δ_0 More precisely, if $\mu_i (\mu_j)$ is the mean DEA efficiency of region i (j), then $\mu_i - \mu_j = \Delta_0$. Table 3 shows the main data related to the statistical tests of the performance.

Test 1 assesses if Korea is 5% more efficient than Japan. Test 2, if Korea is 5% more efficient than China and so on.

The *p*-value helps to decide if the null hypothesis should be rejected or not: if the *p*-value is lower than the significance level, then the null hypothesis cannot be rejected. Thus, for a significance level of 10%, only test 3 cannot be rejected, or in other words, the statement "Korean shipbuilders are 10% more efficient than European shipbuilders" cannot be rejected. All the other affirmatives can be rejected for a significance level of 10% or less.

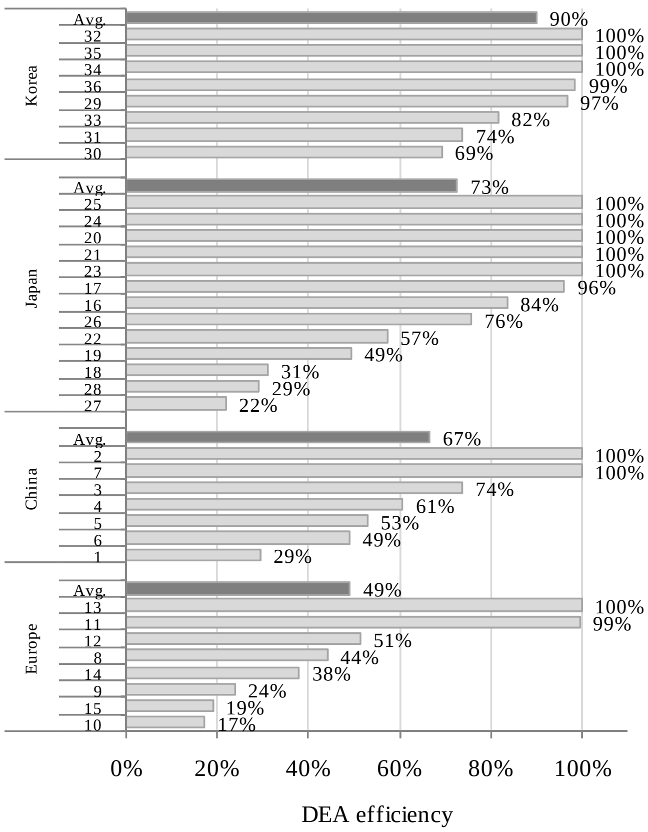

Figure 5: DEA efficiency of companies and regions

Table 3: hypothesis tests for differences in efficiency

Test	Region		Null hypothesis	*p*-value
	i	j	$\mu_i - \mu_j = \Delta_0$	
1	Korea	Japan	5%	21.9%
2	Korea	China	5%	12.8%
3	Korea	Europe	10%	3.8%
4	Japan	China	5%	41.1%
5	Japan	Europe	5%	22.4%
6	China	Europe	5%	43.6%

The significance level of a test can be defined as the probability of rejecting the null hypothesis when the null hypothesis is actually true. For additional details on statistical concepts, please refer to Montgomery and Runger (1999, chapter 9).

A sensitivity analysis of the data can suggest reference companies for those which are inefficient. A deployment of the study, considering additional details such as the mix of ship types built, might indicate, for a given company, where to benchmark.

4 CONCLUSIONS AND FURTHER COMMENTS

Between 2003 and 2006 dry-dock turnover of the studied sample (which represents more than 50% of worldwide production) grew by 1.18 CGT/m²/year on average, or 5 times faster than that which had been observed between 1987 and 2002. The study does not try to identify the drivers of such impressive improvement, but demand growth is surely one of the most important.

Besides a higher dry-dock turnover, in aggregated terms, Korean shipbuilders have been improving turnover levels faster than anyone else. The conclusion is not only indicative of the success of the Korean strategies, but also of a large room for improvement in regions such as China, Europe and Japan.

A more comprehensive consideration of asset turnover based on data envelopment analysis, including dry-dock, berth and lifting capacities as inputs, and production and ship types as outputs, still indicates the better performance of Korean shipbuilders when compared to others, but the difference becomes smaller. Even Europe, which is frequently cited as decadent in shipbuilding, shows 2 (out of 8) efficient companies.

Hypothesis tests were used to compare performance across the regions. Only the affirmative that Korea is 10%

more efficient than Europe cannot be rejected. All the other affirmatives tested (Korea is 5% more efficient than Japan, Korea is 5% more efficient than China, Japan is 5% more efficient than China, Japan is 5% more efficient than Europe and China is 5% more efficient than Europe) can be rejected at a 10% significance level.

Inefficient companies could use the proposed method and database to compare its individual performance against competitors and identify reference companies to be used as benchmarks in their segment.

Although it is evident from the previous discussion, it is important to reinforce that efficiency as studied here is far from being representative of the overall capability of the company. For instance, financial profitability is an important proxy of the overall capability that has not been taken into account here; an underperforming company from the DEA perspective may show good financial performance, and the other way round. In fact, productivity is not necessarily correlated to financial performance; for example, better financial results are associated with less mechanization in smaller wages countries. Also, as pointed out by Murillo-Zamorano (2004), DEA does not distinguish between technical inefficiency and statistical noise effects.

5 REFERENCES

BODIE, Z., KANE, A. and MARCUS, A. J. 2001 *Investments*. 5th ed., McGraw-Hill/Irwin, New York.

BURNS, D. C., SALE, J. T. and STEPHAN, J. A. 2008 A better way to gauge profitability, *Journal of Accountancy*, **206**, 2, 38-42.

CHARNES, A., COOPER, W. W. and RHODES, E. L. 1978 Measuring the efficiency of decision making units, *European Journal of Operational Research*, **2**, 429-444.

COLIN, E. C. 2007 *Operations Research*: *170 Applications in Strategy, Finance, Logistics, Production, Marketing and Sales*, LTC, Rio de Janeiro. (in Portuguese)

GEBHARDT, L. P. and JARVIS, R. G. 2003 Productivity improvement at the SENESCO shipyard, *Journal of Ship Production*, **19**, 3, 187-193.

KOENIG, P. C., NARITA, H., and BABA, K. 2003. Shipbuilding productivity rates of change in East Asia. *Journal of Ship Production*, **19**, 1, 32-37.

LAMB, T. and HELLESOY, A. 2002 A shipbuilding productivity predictor, *Journal of Ship Production*, **18**, 2, 79-85.

MELLO-e-SOUZA, C. A. de and AWASTHI, V. N. 2009 Probing financial statements in a post-Sarbanes-Oxley world, *Strategic Finance*, April, 37-45.

MONTGOMERY, D. C. and RUNGER, G. C. 1999 *Applied statistics and probability for engineers*, 2nd ed., Wiley, New York.

MURILLO-ZAMORANO, L. R. 2004 Economic efficiency and frontier techniques, *Journal of Economic Surveys*, 18, 1, 34-77.

PIRES Jr., F. C. M and LAMB, T. 2008 Establishing performance targets for shipbuilding policies, *Maritime Policy & Management*, **35**, 5, 491-502.

STORCH, R. L., HAMMON, C. P., BUNCH, H. M. and MOORE, R. C. 1995 *Ship Production*. 2nd ed., Cornell Maritime Press, Centreville, Maryland.

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