Origins and Development of the Danish Shipbuilding Industry 1854—1932[1])

Af Paul F. Mc Gouldrick

I

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Nor is the industry's relatively modest status likely to change for the better in the near future. Relative to industry in general, shipbuilding has been falling behind since the beginning of the Great Depression. The industry that pioneered the Diesel-motor ship is now said to be afraid of Swedish competition in the domestic market if the proposed Nordic customs union were to become a reality. Whatever may be the causes, and this paper cannot go into them, the fact is unquestioned that shipbuilding has been almost stagnant for two decades.

But up to the Great Depression, we have quite a different picture. Shipbuilding was the first Danish industry to have a high ratio of real

[1]) Forfatteren, der er M.A. fra Harvard University, har udarbejdet artiklen under et studieophold ved The Danish Graduate School for Foreign Students i København. Artiklen prætenderer ikke at bringe egentlig nye oplysninger, men må tages som udtryk for de resultater, en udenlandsk økonom er nået til ved studier i Danmark. (Red.s anm.).

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capital to employment and output; and its history, from its origins in the middle of the 19th century to the Great Depression, was marked by incessant innovation in the Schumpeterian sense. Its establishment and early growth was a triumph of entrepreneurial struggle against disadvantageous transportation costs for raw materials and the scarcity of skilled laborers and engineers that reflected the economy of a primarily agricultural country. And between 1913 and 1930, Danish ship launchings increased from 2.1 percent and 1.2 percent of English and world launchings to 9.3 percent and 4.8 percent respectively. The innovation of the Diesel motor ship has already been mentioned: it was the main force behind the industry's great post-war expansion.

This paper will mainly be confined to this period of growth between 1854 and 1933 and will analyze the industry's history from the standpoint of seeking out the growth factors and evaluating their relative importance. The material divides itself into four periods. The first covers the genesis of the industry in the single firm of Burmeister & Wain A/S, between the first Danish launching of a steel ship in 1854 to the firm's incorporation in 1872. The second may be said to date from 1872 to the innovation of the Diesel motor ship and was characterized by the entrance of a second firm, Helsingør Skibsværft A/S and a slight decline in the rate of growth. The third period centered around the development of the Diesel motor ship, and the fourth period was marked by a powerful post-war expansion of Burmeister & Wain and the entry of a number of provincial firms into the industry.

II

Shipbuilding in Denmark dates back to the age of the Vikings, and there is a long history of mercantilist policy towards the industry between the 16th and the 19th centuries. But construction of wooden sailing ships never assumed great proportions before it gave way to steamship construction.

Mercantilist policy had wavered between encouraging shipbuilding and shipping and commerce, since their interests as to prices of new ships were directly opposed. Before the separation of Denmark and Norway by the Treaty of Kiel (1814), the latter country had had a clear comparative advantage in shipbuilding. The stimulus that might have been provided by the separation after 1814 was offset by the near-comatose state of shipping and the swing away from mercantilism that dominated State economic policy after the Napoleonic wars[2]).

[2]) Scharling & Falbe-Hansen, *Danmarks Statistik* (Vol. II), section on shipbuilding.

Between 1836 and 1837, the State customs reports show that only 376 tons of ships were constructed a year. We may note a shift of the industry away from the capital to the provincial cities[3]), but aggregate output did not seem to be affected by this structural shift.

Nor was it the established wooden-shipbuilding firms that made the jump to steel shipbuilding later. These firms had constructed a few small wooden steamships before 1854, the first having been built in 1830. But the impetus, as in England, came from an outside and apparently unrelated industry. The firm of Baumgarten & Burmeister had been founded in 1846 to construct steam engines, boilers, and other steel shapes and installations. At that time, neither of the partners had had the faintest notion of going into shipbuilding.[4]) But the firm's workshop was conveniently located, on a canal in Christianshavn, and the Royal Navy was seeking a domestic supplier of the steel ships coming into use.[5]) The firm launched its first ship, a wooden Postal sternwheeler, in 1854. A year later, it constructed the first steel steamer built in Denmark, a 114 ton troop transport. A series of 11 of these were built before 1861.

The firm's two partners, Hans Baumgarten and Carl C. Burmeister, are important both in the history of shipbuilding and the history of Danish entrepreneurship. It is significant that they had spent long periods of work and study in the more industrially advanced economies of England and Germany. Baumgarten had worked at the *Vossische Zeitung* printing shop in Berlin for three years. Later, he made a five-months tour of machine shops in England, France and Belgium to study their techniques. Burmeister had lived abroad for four years, studying in Paris and then working at the Hommel and Börsig machine shops in Berlin. But unlike study trips in the mercantilist days, their study was financed entirely through their own earnings and by private grants (the Reiersenske fund).

The two men were quite different in personality and training, however. Baumgarten was the practical mechanic, resembling closely the

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[3]) Rawert, *Kongeriget Danmarks Industrielle Forhold*, section on shipbuilding.

[4]) All data in this section not otherwise footnoted is taken from the 1907 jubilee report of Burmeister & Wain.

[5]) More research is needed on the role of the Royal Navy in fostering Danish economic development in the 1850's and 1860's. It had the most modern machines and installations in Denmark at the dockyard in Copenhagen, and its schools trained a number of mechanics who later rose to ownership or management of engineering and foundry firms. William Wain, Burmeister's partner after 1865, was employed there.

English machine-shop owners of the time, while Burmeister had acquired a thorough academic training at the *Polytekniske Læreanstalt* in Copenhagen. As in many other things Danish, there is an intermingling of two streams of influences from England and Germany, of English practical emphasis and German academic-theoretical bent.

Up until 1860, the shipbuilding department was very tiny. Of the 11 ships built, all were on State account. A large relative expansion took place between 1860 and 1865, 18 ships being built for the State and 10 for private shipping companies. And while the number of ships built fell to 23 in the 1866-71 period, average tonnage rose from 144 (1861-65) to 414. It is more significant that State orders ceased to be the mainstay of the shipbuilding department: 20 of the 23 ships constructed were sold to private shipping companies.

If any turning point can be located in this period, it is the year 1865. Denmark had been defeated in the war with Prussia and Austria a year earlier, and the prop of State military orders had been withdrawn. The domestic shipping industry was beginning its rapid growth that has persisted to the present; but Danish shipowners had always been accustomed to purchasing most of their requirements abroad. The English lead in steel ship construction was being nailed down in those years; and it is just as conceivable that they would have supplied the requirements of Danish shipowners as that a Danish industry would have grown up. In retrospect, it would perhaps have been natural if the shipbuilding department of the firm had been discontinued. Instead, William Wain, an assistant director of the Naval dockyards (Orlogsværftet), was chosen as Burmeister's new partner after Baumgarten's retirement in 1865. An Englishman by birth and early training, he had a string of inventions to his credit, including a floating dock, a new type of ships propellor, and a redesigned ship's steam engine. By training and inclination, he was interested in shipbuilding rather than machine-shop work; and he assumed the leadership of the shipbuilding section. The first ten years after his arrival show the fastest rate of growth of output in the firm's, and the industry's history. The firm's incorporation in 1872 was necessitated by this expansion and the consequent need for a completely new shipyard to handle it. In place of the tiny yard in Christianshavn (measuring 150 by 150 feet), a shipyard was built at Refshaleøen, one mile from the engine works. It had two building berths and was on about three times the scale of the earlier yard, having also repair slips and subsidiary workshops.

The incorporation itself was managed by C. F. Tietgen, chairman of

the *Privatbank* and promoter-extraordinary. He became chairman of the board, with Burmeister and Wain continuing to manage the machine shops and the shipyards respectively. Until his retirement in 1898, Tietgen managed the firm's finances and made it his business to seek orders.

III

The chart on page 126 shows the growth of shipbuilding from 1861 to the present. The output was contributed to by Burmeister & Wain A/S

Three-Years Moving Average of Danish Deliveries of New Steel Ships, 1861—1950.

(gross registered tons, rounded off to nearest 10 tons (before 1883) or nearest 100 tons (after 1883)).

Year	*Tonnage*	Year	Tonnage
1861	110	1891	11,500
1862	180	1892	14,600
1863	540	1893	8,600
1864	950	1894	6,400
1865	990	1895	7,300
1866	640	1896	10,800
1867	540	1897	12,400
1868	790	1898	14,400
1869	1,250	1899	12,900
1870	1,960	1900	13,600
1871	2,550	1901	14,100
1872	2,680	1902	17,300
1873	1,960	1903	17,900
1874	2,740	1904	14,900
1875	3,570	1905	15,100
1876	3,820	1906	19,000
1877	2,720	1907	19,700
1878	1,890	1908	14,100
1879	2,410	1909	9,000
1880	2,510	1910	7,400
1881	4,130	1911	14,700
1882	5,280	1912	22,100
1883	7,400	1913	30,700
1884	6,800	1914	34,700
1885	4,600	1915	33,200
1886	2,200	1916	29,500
1887	2,900	1917	22,700
1888	6,400	1918	21,600
1889	10,200	1919	30,900
1890	11,200	1920	50,100

(Continued next page).

1921	59,300	1936	107,700
1922	55,500	1937	121,300
1923	48,800	1938	137,200
1924	56,400	1939	124,900
1925	69,700	1940	92,300
1926	74,100	1941	69,800
1927	93,000	1942	52,600
1928	96,900	1943	42,600
1929	123,500	1944	52,400
1930	119,400	1945	47,700
1931	104,000	1946	69,100
1932	60,400	1947	72,100
1933	40,600	1948	93,500
1934	62,500	1949	101,700
1935	85,400	1950	106,100

until 1883, by this firm and Helsingør A/S from 1883 to 1903, and by the whole industry from 1903 to 1950.[6])

Confining ourselves to the period 1872—1907, we note that output rose from a cyclical peak of 3,900 tons in 1876 to a corresponding cyclical peak of 19,500 tons in 1907. The following table[7]) shows the growth in the labor force of Burmeister & Wain during this period, as well as before.

The reliability of many of the years is questionable, unless the compiler rounded off the figures before presenting them. Similar yearly data

1850	65	1880	1,400	1894	1,600
1855	110	1881	»	1895	2,000
1860	300	1882	»	1896	1,900
1865	480	1883	1,480	1897	1,793
1871	900	1884	»	1898	2,100
1872	900	1885	1,200	1899	1,900
1873	1,200	1886	»	1900	1,600
1874	»	1887	»	1901	2,100
1875	1,400	1888	»	1902	»
1876	»	1889	1,500	1903	2,887
1877	1,200	1890	»	1904	2,200
1878	»	1891	1,800	1905	2,000
1879	1,500	1892	»	1906	3,000
		1893	1,268		

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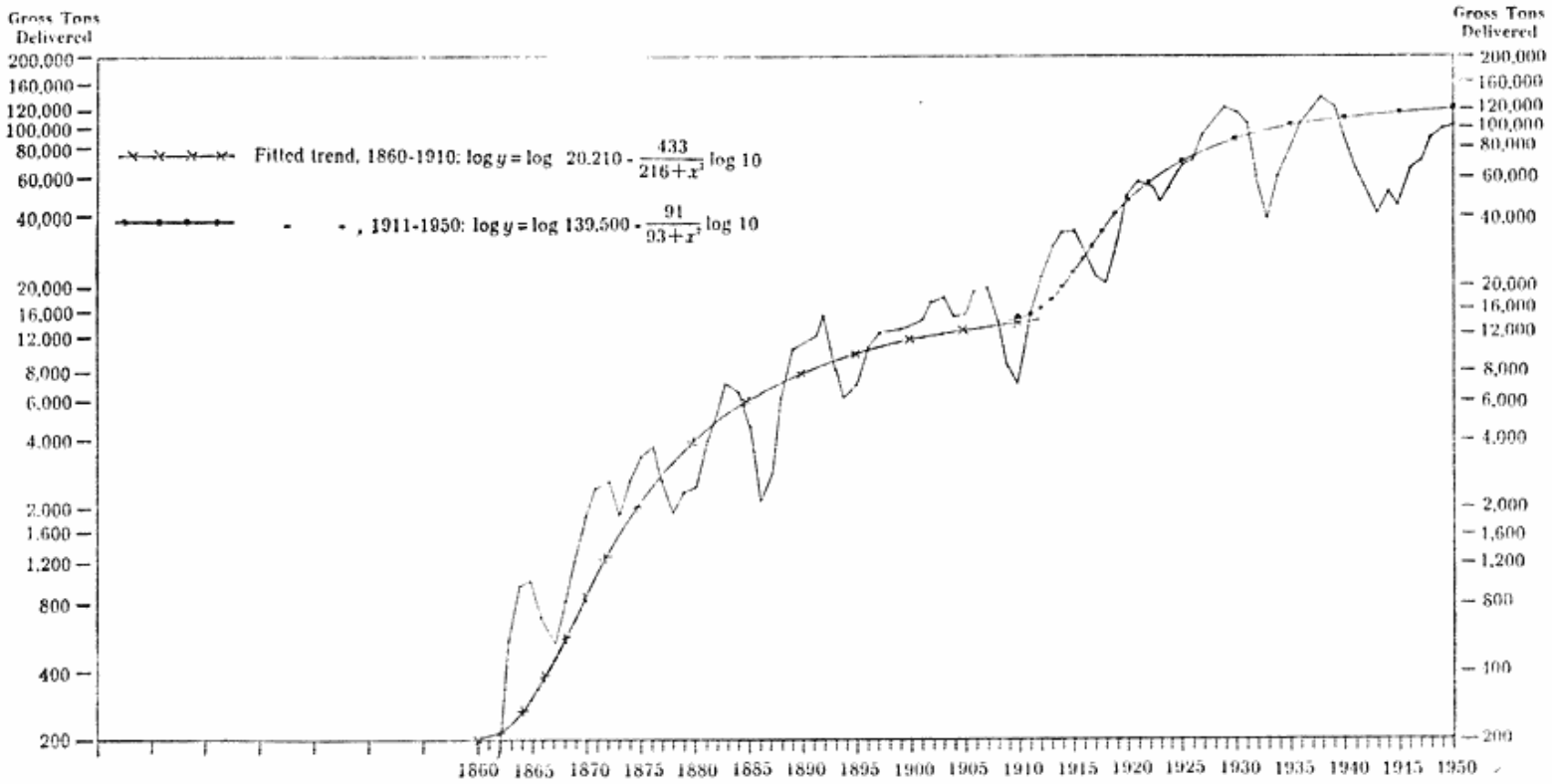
[6]) Charted from three-year moving average of shipbuilding deliveries, see table p. 124. Sources were the *Industriberetningerne* after 1903 and the 1906 and 1907 jubilee reports of Burmeister & Wain and Helsingør respectively. For the period 1906—1929, figures in net registered tons were converted into gross ton equivalents, introducing a slight source of error for these years.

[7]) Seasonal fluctuations within this industry are very large.



Danish Steel Ship Construction 1860–1950.
(Three-years moving average)

is not available on the labor force of Helsingør A/S after 1883. The firm employed about 700 workers in 1883 (at the top of a cyclical prosperity phase), which fell to 231 employees three years later. By 1906, employment had risen to a seasonal maximum of 900 men.[8])

To round off our picture of the main contours of growth in this period, a measurement of the growth of fixed capital in both firms is desirable. The difficulties of measuring growth of real capital are notorious,[9]) and lack of time has made the writer unable to deflate his figures by a suitable index of prices. Still, the following series for Burmeister & Wain offer a fairly accurate picture of changes in the corporation's stock of fixed capital between 1871 and 1907,[10]) if it

Growth of the Fixed Capital Component of Burmeister & Wain A[S
(in thousands of Kroner).

Year	*Value of Fixed Capital*	*Annual Increment*	*Year*	*Value of Fixed Capital*	*Annual Increment*
1872	2,842		1890	6,753	70
1873	3,700	858	1891	6,764	11
1874	.....	1,039	1892	6,808	44
1875	5,778	1,039	1893	6,837	29
1876	5,782	4	1894	6,726	— 111 a)
1877	5,779	— 3	1895	7,798	1,071
1878	5,754	— 25	1896	7,904	107
1879	5,751	— 3	1897	7,906	2
1880	.....	29	1898	8,334	427
1881	5,810	29	1899	9,055	722
1882	5,861	51	1900	9,269	214
1883	5,913	50	1901	9,485	216
1884	6,456	543	1902	9,828	340
1885	6,455	— 1	1903	10,137	309
1886	6,495	40	1904	10,597	460
1887	6,593	98	1905	10,842	245
1888	6,616	23	1906	11,110	267
1889	6,683	67	1907	12,725	1,615

a) Purely a book-keeping change: writing-down of value of floating dock constructed in 1884.

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[8]) 1907 jubilee report of Helsingør A/S. This is not as informative a source as the ubilee report of B & W a year earlier, but it has some interesting material on opposition to Tietgen's leadership in the 1870's and early 1880's. All data in this section on Helsingør A/S is taken from this source, unless otherwise footnoted.

[9]) The reader may be referred to Colin Clark, *The Conditions of Economic Progress*, for a discussion of this problem (Chapter XI).

[10]) The source was the annual financial reports of the firm. Categories of assets included were land, buildings, installations, machinery, and inventories of materials. The last-named item could not be separated out from the other items, as would be theoretically desirable. The firm followed a factor-cost method of accounting. Changes in book value of fixed capital items were reported, but they seem to have been very few.

is kept in mind that prices of capital goods were gradually falling until the mid-1890's and therafter rising.

Data offered by the annual reports of Helsingør A/S is unsuitable for purposes of comparison. (The firm seems to have followed a bookkeeping policy of its own, writing down the value of fixed capital to figures far under its real replacement value). Two years after the corporation's birth, its fixed capital was valued at 1,458,000 Kroner, about $^2/_9$ths of the fixed capital value of Burmeister & Wain. Valuation fell until 1897, when an expansion nearly doubled the value (2,675,000 Kroner). No further major investments were made for 10 years.

From these series and the data in the jubilee reports of the two firms, two facts stand out. Output continued to expand, taking the two firms together. But something very close to stagnation marked the shipbuilding department of Burmeister & Wain in these years, until an expansion of the Christianshavn engine works in the 1895—1905 period carried with it some expansion of shipbuilding capacity (through expanding capacity of the foundries and forges fabricating shipbuilding parts and sections). Expansion of aggregate output was made possible only by the entrance of a second firm to the industry and its expansion in 1897.

The levelling-off of shipbuilding output at Burmeister & Wain was largely associated with the personalities of its leaders. William Wain continued managing the shipbuilding department until his death in 1885. And under his leadership, a third building berth was laid down in 1881 and a floating drydock constructed in 1884. He was succeeded by David Halley, another Englishman, in 1885. Halley was reputedly capable but narrow-minded with respect to the new technological methods being introduced in American and German machine shops. Under his leadership, the engine works at Christianshavn were allowed to remain in about the same state as they had been in 1875.

C. F. Tietgen also played a role that affected the firm's progress. Little is known of his business policies in spite of several Danish biographies, but they may be inferred from the firm's jubilee reports and Schovelin's biography. Of the salesman-promotor type, he busied himself with the firm's finances (arranging, for example, a Kroner 2 million loan in 1884) and with securing orders through his connections. (He was also president of Det Forenede Dampskibsselskab, Denmark's largest shipping company, and had connections with the Russian court via the Danish royal family). Under his leadership, the firm followed a policy of paying out large sums in dividends and making only such investments as were immediately profitable in terms of a short-run

demand estimate. »By 1895, the firm was kept running solely on its prestige and on Tietgen's influence in securing orders«[11]).

After 1895, a dramatic change took place in the company's investment policy. David Halley died and was succeeded by Commander Nielsen; and key positions in the firm were filled with new men in that and the following years. It is significant that all of the new men were Danish. Up to then, both Burmeister and Wain A/S and Helsingør A/S had depended heavily on foreign engineers and on foreign training of their own leaders: witness Baumgarten, Burmeister, William Wain, Vilhelm Dyhr of Helsingør A/S, and David Halley. Dependance had also extended to lower levels of management: a Frenchmen and a Belgian were engaged in 1855 as the two foremen of the Burmeister & Wain shipbuilding yard. Now, the industry was capable of training its own foremen and procuring Danish engineers and managers of the best type, such as Ivar Knudsen.

From 1895 through 1905, Burmeister & Wain spent over 4 million Kroner in expanding the engine and foundry works at Christianshavn. The details need not detain us, except to note that the effect was an almost complete replacement and $1^4/_5$ths expansion of the former plant coupled with installation of such units as a hydraulic press of over 1 million kilograms force and a Siemens-Martin steel furnace (melting down industrial scrap recovered in the Copenhagen area). The investment was financed through a 2 million Kroner bond issue in 1897 and a new policy of plowing back profits[12]).

This increased shipbuilding capacity only indirectly, through increasing capacity to fabricate shipbuilding forms and sections. But shipbuilding output increased considerably as a result. The trend was steadily towards larger types of ships and towards exports. While only three ships had been sold to commercial foreign buyers in the 28 years before 1900, 15 were sold in the following seven years. Only one ship was built in the 1870's of over 2,000 tons, but the firm was constructing ships of over 5,000 tons 30 years later.

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[11]) 1907 jubilee report.

[12]) The writer has calculated that the average difference between gross and net earnings (Brutto- og Nettooverskud) increased from 367,000 Kroner in 1885—95 (annual rate) to 789,000 Kroner per year in the 10 following years. This indicates that quite a lot of capital for re-investment was squeezed from dividends in the latter period. Another proof: no dividends were paid in 1903, although gross profits were higher than in 1891, a year when 200,000 Kroner were paid out in dividends.

Exports and Domestic Sales of Ships by Burmeister & Wain, 1861—1907

Period	*Nationality of Buyer*	*No. of Ships Delivered*
1861— 72	Danish	62
	Foreign	0
1872—1900	Danish	108
	Foreign:	8
	Russian government	5
	German	3
1900—1907	Danish	23
	Foreign:	15
	Norwegian	6
	German	5
	Swedish	3
	French	1

Ships Constructed by Burmeister & Wain, Classified by Weight.

Period	0—1,000 tons	1,000—2,000 tons	2,000—5,000 tons	Over 5,000 tons
1860—70	57	1	0	0
1871—80	39	15	1	0
1881—90	25	20	3	0
1891—1900	27	10	7	1
1901—06	14	17	5	2

Helsingor A/S, however, was the main cause of the industry's continued growth. It was formed in 1882 through the efforts of M. C. Holm and Vilhelm Dyhr, with a conflict between these men and other interested persons, and C. F. Tietgen on the other side playing a considerable role in the background. Like Burmeister & Wain, Helsingor A/S was planned for making ships repairs and steam engines (for its own ships and for other industries) as well as for constructing ships. Location in Helsingor seems to have been a result of that city's favorable position on a major shipping route, plus certain difficulties (connected with M. C. Holm's conflict with Tietgen) in locating a second shipbuilding firm in Copenhagen [13]).

The shipyards and machine shop were constructed with great speed, and the firm delivered five ships in 1884. But it had been formed near the peak of a shipbuilding cycle, and it nearly collapsed in the following

[13]) The firm's 1907 jubilee report goes into this in some detail. This report is also the source of all data on Helsingor A/S in this section, unless otherwise footnoted.

slump. It was barely kept going by a State order for one ship and a *Kassekredit* of 500,000 Kroner from the *Landmandsbank* (again the thread of revolt against Tietgen's leadership!), until business picked up in 1887 and 1888.

No major investments were made by the new firm until 1897, but in two years, the firm's fixed capital was nearly doubled. The expansion was of much the same kind as the parallel one at Burmeister & Wain, an increase in scale being combined with replacement of obsolescent equipment. (Examples of the kind of investment were: replacement of a 45 ton crane at the dock with a 80 ton crane, construction of a 372 foot drydock, and construction of an additional hauling-up repair slip). This was sufficient to meet the firm's orders until World War I. Output of ships continued to be slightly under Burmeister & Wain's deliveries, measured by gross tonnage constructed.

The Copenhagen Floating Dock Company (Kobenhavns Flydedok A/S) was founded in 1897, with a capital of 700,000 Kroner. This was increased to 1 million Kroner by 1907, and the labor force had risen to 700 workers and foremen for that year. But the firm's activities were concentrated around ships repairs, and data on shipbuilding is lacking before World War I.

IV

Up to 1900, the bread and butter of the industry had been ships repairs plus the construction of relatively small vessels for the domestic shipping industry. This market required smaller ships of the most diverse types: passenger ships, ferries to connect the Danish islands, heavier freighters for coal and grain, small passenger and freight ships for runs from Copenhagen to the provincial cities, and such diverse types as ice-breakers and refrigerator ships to carry butter and livestock products to England. Foreign orders were occasional and marginal placed with Danish firms when English or domestic yards were booked solidly with orders.

Consequently, construction of large ocean-going vessels was almost non-existent. It was not until 1899 that the East Asiatic Company (Østasiatiske Kompagni) placed its first order for a long-distance freighter of over 5,000 tons. These orders grew rapidly during the following decade. But it is doubtful whether a solid market could have been won if Burmeister & Wain had not contributed its major innovation, the Diesel motor ship. This made possible the transformation of the

company into a large and continuous exporter of ships and was the basis for the great post-war expansion of this firm and the creation of new firms after 1916.

Burmeister & Wain was only one of many firms negotiating with Rudolf Diesel in 1898—99 for licenses to construct his motor. And the contract as signed provided only for sales rights within Denmark itself. But as with many other inventions, the improvements grafted on proved to be more important than the original model. Director Ivar Knudsen was in the fortunate position of being both a zealous engineer and one of the directors of the firm, and considerable amounts of money and time were devoted to the improvement of the original uneconomic motor. This took five years before such problems as fuel injection and atomization could be solved and the first motor put on the market in 1904. Manufacture for stationary use increased rapidly. The power of units constructed increased from 160 hp. in 1904 to 360 hp. (1907) and 600 hp. (1909).

On top of the three to four years necessary for the gestation of the stationary Diesel motor, the firm had to spend three years in designing the world's first Diesel motor ship, the Selandia, and working out design and engineering problems that became apparent only in the process of construction and operation of the ship. Some of these problems might be cited, such as designing a motor that could run both forward and in reverse, making it more compact and box-shaped to fit a ship's hold, and increasing the horsepower to 2,500 units per engine. More important in an economic investigation like this, however, is the fact that the firm had the staff, equipment, and financial capital to bring the Diesel motor forward over two gestation periods of four and three years, during which this work brought in no or insignificant income. It could design and build its own machine tools for some processes which required far closer tolerances in engine parts than any required for steam engines. It could bear the risk that foreign firms might race ahead of it and bring out an improved motor that would destroy the market for the motor it was trying to build. It is obvious that the economic problem here is of quite another kind than that of setting up a textile or even a machinery factory copied after foreign models, of taking over an existing industrial process and administering it. Here, we have an example of the Schumpeterian innovation process that was not duplicated in the rest of the Danish economy, most of which was still very spottily industrialized.

The *Selandia* became a sensation in the shipping world when it was

completed in 1912: it was visited by both Winston Churchill, First Lord of the Admiralty, and Kaiser Wilhelm II of Germany. But the firm was caught unprepared by its own success. The shipyard was still of the same size of 20 years before, with only three building berths. For this and, we may presume, other reasons, the firm decided on a policy of extensive licensing of its ships Diesel motor. An English factory was quickly built of double the size of the Danish plant, operated by a subsidiary of Burmeister & Wain. By 1925, firms in Austria, Germany, England, and the United States had been licensed to construct the motor, including such noted ones as Harland and Wolff in Belfast and S/A John Cockerill.

But domestic output of these motors also increased steeply from 1906 to 1931, with the exception of the structural break caused by World War I and the consequent near-stoppage of Danish ship construction.

Horsepower of Diesel Motors Delivered by Burmeister & Wain, 1906—1931.

Year	*Horsepower of Motors*	*Year*	*Horsepower of Motors*	
1906	1,497	1920	12,885	
1907	1,921	1921	21,005	*Of this HP Delivered to other Shipyards*
1908	2,559	1922	28,125	
1909	4,470	1923	30,235	
1910	6,554	1924	48,055	
1911	6,964	1925	80,910	
1912	16,031	1926	114,300	96,330
1913	19,358	1927	88,895	66,340
1914	20,648	1928	148,148	106,433
1915	16,060	1929	145,180	94,645
1916	12,895	1930	181,765	121,185
1917	5,780	1931	110,659	63,850
1918	5,875			
1919	8,200	1952	177,032	

Source: 1922 jubilee report and *Industriberetningerne*.

The expansion of the Christianshavn engine works after the war will be analyzed in the next section. Turning to shipbuilding, the yard was booked up with orders immediately after the *Selandia*'s maiden voyage. In 1915 and 1916 alone, more than 30 ships were ordered; and between 1912 and the end of 1915, it delivered 18 motor ships, most of which were sold to the Danish East Asiatic Company and a Swedish company, *Aktiebolaget Nordstjernan*. All of them were over 5,000 gross tons in weight, as compared with the much smaller ships built earlier. This

represented the utmost that the yard could produce: fixed capital was strained as far as it could[14]).

The World War thus came at the worst possible time for the Danish industry. It would never have achieved, or tried to achieve, anything like a monopoly on world construction of Diesel motor ships. It was impossible both technologically (the patents taken out by B & W had only a very limited coverage) and economically. But the country's industry had a head start, and it might have been able to conquer a much larger share of the world market than it finally did if the war had not stimulated Diesel production and improvement in the belligerant countries and crippled Danish shipbuilding through the shortage of steel.

V

Between 1907 and 1931, a number of new firms entered the industry, most of which went into bankruptcy in 1921—24 and in the Great Depression. Four hung on, the shipyards at Aalborg, Odense, Nakskov, and Frederikshavn. One company, Københavns Flydedok A/S, disappeared through merger with Burmeister & Wain. Helsingor A/S pursued a steady course, neither expanding nor falling behind. Burmeister & Wain more than trebled output and its stock of real capital before becoming deeply involved in the Great Depression. Thus, the firms comprising the industry were pursuing increasingly divergent investment policies as their scale and output composition grew apart.

Helsingor A/S, for example, pursued a very different policy during these years from Burmeister & Wain's. Instead of a large expansion of output and investment, we have a picture of a firm that had settled down to maturity, making small improvements and following the drift of technological and market changes but preferring security to risk. The trend of tonnage produced and employment between 1900 and 1926 was virtually horizontal, with wide cyclical fluctuations around it. From 1926 through 1931, employment rose sharply, to 2,400 workers and foremen at the 1930 peak. But this was an episode rather than a trend. No major additions were made to the stock of fixed capital, and the Great Depression restored employment to the old level. The firm did not suffer nearly as much as Burmeister & Wain and some of the smaller

[14]) Advantages of the Diesel motor ship over the steamship were considerable and should be mentioned here. They had a longer range and freed about 10 percent of carrying capacity for cargo use. About 10 men were saved on a 5,000 ton freighter because of the lower labor requirements. Also, ships were cleaner (absence of coal smoke).

firms at this time. In 1932, minimum employment was 1,000 men, only 650 workers under the minimum-employment figure for the peak year 1930.

Nore were there any major expansions and alterations. Inspection of the firm's 50-year jubilee report of 1932 and of the annual corporation reports fail to show a single increase in scale such as a new building berth or machine shop. On the other hand, the firm was keeping abreast of the market and increasing the size of ships constructed, although not

Ship Construction by Helsingør A/S, According to Sizes of Ships.

Period	20—1,000 tons	1,000—2,000 tons	2,000—3,000 tons	Over 3,000 tons
1901—10	15	24	6	0
1911—20	5	24	4	1
1921—30	4	20	10	2

Source: 1932 jubilee report.

specializing in the larger ships, as other yards were. Instead, the firm was continuing to concentrate on the smaller sizes of ships for the domestic and Baltic shipping trade, while B & W and even the smaller yards were changing to the construction of larger Diesel-motor ships.

Also, the firm continued to rely on domestic orders. Of the 75 ships delivered between 1911 and 1931, only 16 were exported. And most of these 16 deliveries were contracted for in peak cyclical periods, when, it may be assumed, shipping companies found it impossible to obtain quick delivery of orders from established »exporting« shipyards.

But while Helsingør A/S had reached a stable plateau, the exact opposite is true of the many small provincial shipbuilding companies that mushroomed up during the closing years of World War I. The Diesel motor ship innovation and the intense activity of the established companies before 1915 had awakened general attention to shipbuilding. And demand promised to be at a record high level after the war, as a result of submarine sinkings. What happened was a rash of promotions that contrasts startlingly with the pre-war record of the industry and with facile generalizations on the Danish character. Five shipbuilding companies were founded in 1916, three in 1917, and two in 1918, with share capital aggregating 11,7 million Kroner at the end of 1918. It seemed that every provincial city facing sea water was to have its own shipbuilding company, for a time.[15])

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[15]) Capital seems to have come mostly from local sources, although this can only be guessed at.

The winnowing-out process began in 1920, and five had been liquidated and two virtually gone out of business by 1924 (capital written down from 4 million and 1,5 million Kroner to 200,000 and 75,000 Kroner respectively). The firms had been unable to obtain the necessary steel during the 1919—20 boom, and the subsequent depression finished most of them off. They did not have the repair business enjoyed by Copenhagen and Helsingør yards to fall back on, and capital had been very slender when measured against the steep rise in steel and equipment prices from 1917 to 1920.[16])

Four were left, the Aalborg, Nakskov, Frederikshavn, and Odense shipyards. The Aalborg yard barely hung on during the whole period; it went into bankruptcy in 1927 and was reorganized a year later, with an increased share capital of 500,000 Kroner. It delivered two ships each in 1929 and 1930, but then orders vanished during the depression years. The writer has found only one report in the *Industriberetningerne*[17]) on the Odense shipyard: that it constructed the very respectable total of 34,300 tons of ships in 1929. Another yard emerged from bankruptcy in the middle 1920's, Svendborg A/S; but it limped along for the rest of the decade and went bankrupt again in the Great Depression. On the other hand, Nakskov Skibsbyggeri A/S put on an astonishingly good performance. For the years reported, we have figures of 5,200 tons constructed in 1924, about 20,000 tons in 1927, 10,400 tons in 1929, and 26,000 gross tons delivered in 1931. Even in 1933, the yard delivered 8,200 tons of ships, although they were very small and three were State orders.[18])

Thus, the wartime and post-war expansion of the industry did not alter the dominant position of Burmeister & Wain within it. The rise of the smaller yards was offset by the failure of Helsingør A/S to grow and the merger of the Copenhagen Floating Dock Company with B & W in 1926. Its ambitious expansion program, begun in 1919, more than doubled the company's stock of real capital; and both the shipyards and Christianshavn engine works were equally affected by it.

[16]) Only one of the 11 firms had a capital of over 2 million Kroner.

[17]) All data on the smaller shipyards and the Copenhagen Floating Dock Company has been collected from the *Industriberetningerne*. The writer regrets that time limitations have prevented him from visiting the smaller provincial yards. It would be particularly valuable to obtain some information on the cost structure of these yards, i. e., whether they are marginal yards or not at present and in the past.

[18]) For all small yards, repair business became more important than ship construction during the period.

Perhaps the best way of demonstrating this expansion is to present the following time series on tonnage of ships built, employment and wages paid out, growth of the fixed capital component (the same series as on page 127 continued), and net profits declared. Adjustment must be

Year	*Ships Delivered* (gross tons)	*Employment in All Branches of Firm* (at end of year)	*Fixed Capital Component* (000 of Kroner)	*Profits Available for Dividends* (000 of Kroner)
1907	19,750	2,900	12,725	(loss)
1910	6,199	2,479	13,194	600
1912	18,787	2,994	13,894	500
1915	26,719	3,461	14,792	1,000
		Wages & Salaries Paid (000 of Kroner)		
1915	26,719	5,092	14,792	1,000
1916	19,709	5,572	15,412	2,500
1917	3,762	4,168	17,704	2,200
1918	12,606	3,773	19,166	1,800
1919	10,422	8,365	19,665	1,500
1920	15,713	16,382	23,433	1,200
1921	.....	14,157	25,719	1,200
1922	.....	7,175	31,079	1,500
1923	8,878	9,601	34,555	2,250
1924	14,156	17,126	43,718	1,800
1925	.....	15,146	44,874	1,000
1926	30,344	11,917	43,916	1,600
1927	41,422	19,880	52,870	1,840
1928	71,402	22,191	54.953	1,840
1929	41,882	26,261	61,161	2,500
1930	72,312	26,576	66,994	2,800
1931	64,456	18,153	65,606	(loss)

Sources: Series on ship deliveries and wages & salaries compiled from *Industriberetningerne.* Series on fixed capital component and net profits compiled from annual financial statements. See note 10 on method used to compile the fixed capital series.

made by the reader for changes in the price level over the period, and the table on horsepower of Diesel engines should be consulted on page 133. Between 1920 and 1930, however, the trend of prices of investment goods was downward, while wages rose slightly between 1920 and 1930. Accordingly, it is fairly safe to draw the following inferences on capital intensity per worker and on capital-labor productivity between these two years.

(a) Taking a stable price level of capital goods and wage level as

the limiting case, we are safe in calculating that the number of units of real capital per worker doubled at the very least. This can be shown by the following table, where (in the last column) one million Kroner paid in wages represents one »unit of labor« and one million Kroner's value of fixed capital represents one »unit of capital«.

	1920—1930	
Increase in Wages & Salaries Paid	*Increase in Fixed Capital*	*Ratio of Capital-Units to Labor-Units*
62.3%	186.0%	1.43 (1920)
		2.52 (1930)

(b) Productivity in terms of labor more than tripled during this 10 year period. If we take 1,000 tons of ship constructed plus 10,000 horsepower of Diesel motor to represent one arbitrary unit of output, we can repeat our calculations with the same imput-units as under (a). Calculations are as follows:
1920 16 labor-imputs + 23 capital imputs produce 17 output-units.
1930 27 labor-imputs + 67 capital imputs produce 90 output-units.
In other words, 90 output-units were produced by 27 labor-imput units in 1930, while it had taken 16 labor units to produce 17 output units 10 years earlier. Part of the answer, of course, was an increased capital-intensity per worker; this stands out above. But the main factor increasing labor productivity was an upward shift of the production function rather than any movement along it. *For output per unit of capital also increased between* 1920 *and* 1930, *in spite of the fact that fewer units of labor were being assigned to each capital unit.*[19])

It remains to describe the qualitative character of this investment by Burmeister & Wain. The shipyards were doubled in area by the purchase of the remaining two/thirds of Refshaleøen in 1917. Three new building berths were laid down and a new workshop erected for cutting and shaping shipbuilding plates. The length of the old shipbuilding berths were increased by 120 feet, and new and larger cranes were put up for handling larger shapes. The yards were completely electrified,

[19]) It may be objected that the lagged nature of shipbuilding makes it necessary to lag ship deliveries a specified time after imputs of labor. (Capital does not represent such a problem, since yearly increments are small relative to the total stock). Accordingly, the writer has repeated his calculations by taking three-year averages of ship and engine-horsepower unit output and capital and labor imputs, lagging the former by one year (Average for output centers in 1930; average for imput units centers in 1929). Lack of data for ship output in 1921 makes it impossible to repeat the process for 1919 and 1920. The writer obtained an increase in joint productivity about the same as for the calculations footnoted.

and a larger floating dock erected alongside the older one. This represented roughly a doubling of the area and shipbuilding plus ship's repairs capacity of the Refshaleøen yard. In addition, the acquisition of the two yards of the Copenhagen Floating Dock Company in 1927 increased the shipbuilding and repair capacity by something, but not too much, less than the 8,9 million purchase price.

The expansion at the Christianshavn engine works took two directions. First, the foundry department was removed to a much larger plant at Teglholmen, on the other side of the harbor. This was the largest foundry north of Hamburg, and it produced castings for export to England and Sweden as well as for the firm's own engine and shipbuilding requirements. Secondly, the space thus made available was added to by the transfer of the boiler department to Refshaleøen and a purchase of some size in 1928. On this ground were constructed a three hundred foot long assembly and testing hall, as well as a new storage building.

This spurt of investment differed from earlier ones in 1870—74 and 1895—1905 in two respects. First, it was much greater in aggregate terms, even if we take the high 1920 stock of real capital as a base and put the growth in relative terms for all three periods. Secondly, it represented an overall expansion of both the shipyards and the machine shops; wheras previous spurts of investment had been lop-sided, being concentrated in one department. Investment was also more concentrated on the shipbuilding and ships engines departments. The firm had rid itself of its separator business in 1908, selling it to a Swedish firm; and production of steam engines was discontinued after World War I.

The results of this heavy investment were felt first after 1925. Output of Diesel motors rose from 12,885 horsepower in 1920 (a depressed year) to 80,910 horsepower in 1925 and 181,765 horsepower in 1930. (See table on page 133.) Tonnage of ships delivered passed the 1915 peak in 1926 and rose to 72,312 gross tons in 1930, a quadrupling of output in 15 years. (Both 1915 and 1930 were years of capacity production at the shipyards.) Deliveries for export also rose, both in absolute tonnage and relative to total output. The following list of ships delivered in 1929 overemphasizes the importance of exports somewhat; averaged out, exports for the 1925—30 period constituted about one-half of total deliveries. But the firm was now comparable to the largest English shipbuilding firms, with an excellent cost position and capable of accepting bids from the world market on all types of ships (with the exception of passenger ones).

Ships Delivered by Burmeister & Wain in 1929.

Type of Ship	*Tonnage* (gross)	*Horsepower of Diesel Engines*	*Nationality of Buyer*
Passenger & cargo	5,538	4,750	United States
Passenger & cargo	»	»	» »
Freighter	4,532	3,000	Danish
Freighter	4,265	4,000	Norwegian
Freighter	6,866	4,550	English
Freighter	4,549	5,000	Norwegian
Freighter	4,494	4,000	Norwegian
Freighter	3,180	1,800	Norwegian
Inspection ship	497	1,300	Iceland government

But then came the Great Depression. It is not necessary here to describe the havoc wrought in the world shipbuilding industry, except to mention the year 1932 when not a single ship was being built along the Clyde. Like foreign firms, Burmeister & Wain had incurred very heavy capital liabilities to finance its expansion and carry its ever-heavier inventory of ships and machines in process. The increase of stock outstanding, from 10 million Kroner in 1922 to 35 million Kroner in 1930, represented no legal liability. But the firm had also increased its bonded indebtedness from 2,2 million Kroner in 1916 to 16,6 million in 1930. Part of this was composed of a $ 2,000,000 dollar loan floated in 1926; and the firm had to write up the Kroner amortization and interest payments when Denmark followed the pound and depreciated the Kroner in 1931.

It is very possible that some of the investments made after 1925 had not been too wise. The purchase of the Copenhagen Floating Dock Company, in particular, may have been a source of weakness, since that company had not been doing too well before its merger. But the immediate cause of the firm's reorganization (read: bankruptcy interrupted by the State) in 1932—33 was its exchange losses, difficulties in obtaining payment for work in process, and heavy drop in orders from 1930 to 1933. These were temporary forces; and *ceteris paribus*, the firm could have continued to expand when world shipping and new ship orders recovered in 1936 and 1937. But *ceteris* and *paribus* went their separate ways, and the shock proved to be a lasting one. It is true that shipbuilding deliveries rose slightly above the 1929—30 level in 1938 and 1939, and accomplishments like the building of two 15,000 ton tankers in 1939 deserve mention. But in essence, the firm was now administering a stable production function rather than creating new ones as had been the case in the 1920's. It, and the shipbuilding indu-

stry as a whole, had reached a maturity that has continued up to the present.

VI

The hypothesis that the Diesel motor ship innovation marked a new stage of growth of the Danish shipbuilding industry was tested by fitting two growth curves, of the general form $y = ke^{\frac{c}{a+x^2}}$, to the chart on page 126. The periods chosen for fitting were 1860—1910 and 1911—1952. Both curves turned out to be exceptionally good fits,[20]) if[21]) we allow for the depressive exogeneous events of the Great Depression and World War II.

This statistical evidence is supported by the historical record. The Danish shipbuilding industry was showing marked signs of stagnation in the first decade of this century; its fluctuations and trend paralleled very closely the fluctuations and trend of British shipbuilding during the same period.[22]) The entrance of the Copenhagen Floating Dock Company (1897) had not given the same impetus to shipbuilding as had the entrance of Helsingør A/S in 1882, and the depression of 1907—1911 was of exceptional severity. Thus, the hypothesis is very plausible that the motor-ship innovation saved the Danish industry from the fate that overtook the much larger British one.

There are also marked parallels between the two periods of maximum growth, 1854—75 and 1912—1930. In both periods, the entrepreneu-

[20]) The writer is indebted to Professor Kjeld Philip for the suggestion of fitting two growth curves to the data.

[21]) The writer first fitted a linear trend of the form $\log y = \log a + x \log b$ to the data, obtaining a good fit for the 1870—1930 period and a correlation coefficient of $r = 0{,}95$. The fit for the periods on both sides was poor, however. Then two growth curves were fitted, and inspection showed a considerably better fit in every decade.

These growth curves are descriptive, and their validity depends on the historical material rather than any mathematical test of correlation or explanation of variance. As it happens, they do satisfy both of these tests better than the linear trend that was also fitted. But it cannot be assumed that there was any »trend influence« operating independently of cyclical fluctuations and brooding over year-to-year changes in output like Justice Holmes' »vague, omnipresent cloud in the sky«.

[22]) This series (reproduced in Schumpeters *Business Cycles*, Vol. II, page 535) shows a fall of shipbuilding corresponding to the Danish one in amplitude and length of period from peak to peak. Before the Diesel motor ship innovation, the two series move very closely together, although the Danish rate of growth appears significantly higher. After the innovation, however, the two series diverge completely, the British turning down (except for the war boom) while the Danish series shows a new growth period. (Output rose sixfold in Denmark between 1907 and 1930, while 1930 British construction was under the 1907 level).

rial influence was dominant, shifts in demand being secondary to shifts in the position and slope of the supply curve. And the resistances to overcome were very great also in both periods. After 1854, shipbuilding had to be established in the face of an extremely small pool of engineers and skilled labor, traditional reliance on purchases of British ships, and a disadvantageous transfer-cost position for raw materials. In addition, the prop of State orders was knocked away after Denmark's defeat in the war of 1864. From 1899 to 1912, Diesel motor and motorship development required large outlays on research and production in the face of strong competition from foreign firms and the danger that they might win the race for building economic — and patentable — motors.

In both periods also, the growth impulse came from machinery rather than shipbuilding. There is first the historical lead of machinery output and investment: 1847—1860 and 1896—1905 were both periods of rapid expansion of the Burmeister & Wain machine shops while shipbuilding was either about non-existent (1855—60) or failing to advance (1896—1905). After these lags, shipbuilding came into its own, based on the previous advance in machinery construction. The placing of Diesel motors on ships was a logical, though not inevitable, consequence of Burmeister & Wain's development of stationary land motors. And the earlier establishment of shipbuilding was dependent on the construction of steam engines of sufficient size and reliability to stand the strains of long voyages away from machine repair facilities. This suggests that the division of economic history into watertight »industry« schemas may cause us to overlook vital relationships between growth in different sectors of the economy.

On the other hand, the differences between these two growth periods must not be overlooked. One is the importance of foreign contributions of techniques and personnel. In the first period, foreign-born and trained personnel was vital. William Wain was a Scotchman, and the two foremen of the first shipbuilding yard in Christianshavn were a Frenchman and a Belgian. But the Diesel motor ship was planned and built by Danish engineers and managers, and the flow of techniques was now two-way instead of one. We have only to compare the 1870's, with their dependence on borrowing English engineering methods, and the first two decades of this century, when Burmeister & Wain established a branch factory in England, of twice the capacity of the Danish home plant, and licensed its motors to German, American, Austrian, and Belgian firms.

After these periods of innovation, the industry went through two periods when output began to decline in its rate of growth. This differs markedly for the periods 1875—1910 and 1930—1952. But according to our schema, the growth of the 1920's was a postponed exploitation of the Diesel motor-ship innovation that would have come five years earlier except for World War I. All the historical records bear this hypothesis out.[23]) Therefore, the difference in the shape of the two growth curves of output can be sufficiently explained by the exogeneous forces (exogeneous to the industry and its market) of World War I and the Great Depression. If these two events had not occurred, we may theorize that ship output would have grown more rapidly than it did in the second and fourth decades of this century, and less rapidly in the 1920's. This would have made the second growth curve much closer in shape and size to the first. (The Great Depression and World War II also flattened the second growth curve.)

The periods 1875—1910 and 1930—1952 have less in common, however. The first period was marked by the entrance of new firms (Helsingør A/S and Copenhagen Floating Dock Company) that is paralleled by the entrance of the provincial shipbuilding firms from 1916 to 1919. The second period shows a rapid decline in the rate of growth: exogeneous forces dominate it almost completely, although even the Great Depression could not prevent shipbuilding from rising to a higher peak in 1937—39 than in 1927—30. But from the middle of the 1920's, growth of demand begins to oust entrepreneurship as a growth factor, exactly as is the case from 1875 to 1910. And leadership also loses its earlier vigor from the 1930's on, paralleling the decline that set in at Burmeister & Wain with the death of William Wain in 1884. Burmeister & Wain became »bureaucratized«, administering a production function and introducing small improvements gradually rather than continuing the incessant investment that had marked the firm's growth from 1916 to 1930. And two of the remaining shipbuilding firms passed under the control of Danish shipping firms, the first case occurring as early as 1927.

To summarize, we have five periods in the industry's history, that may be dated as follows:

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[23]) In 1915, Burmeister & Wain had over 30 orders for Diesel-motor ships, enough to occupy the existing yard for six years. Expansion plans were laid in 1914 and 1915, and the land area of the shipyard was nearly doubled by a purchase in 1916. But the wartime and immediate post-war steel shortage forced a postponement of investment to the 1920's. The same was the case with the provincial firms founded between 1916 and 1919.

1854—1875: Genesis and growth of shipbuilding, at a very rapid rate of increase of output. Heavy investment in a new shipyard in 1872—75. Only one firm in the industry.

1876—1900: Output expanding at a decreasing rate. Entrance of two firms, in 1882 and 1897, explaining most of the absolute expansion in these years. Growth of Danish shipping industry carries expansion rather than dynamic shifts on the supply side.

1900—1915: Rate of increase of output continues to decline to 1911 while under the surface, development of Diesel motor and motor ship is prepared. Motor ship innovation in 1912 causes strong, almost violent, expansion of orders. Beginning of new growth period for industry.

1916—1930: Adjustment to consequences of the motor ship innovation. Powerful expansion of Burmeister & Wain and entrance of 11 firms to industry, four of which survived. The entrepreneurial impulse is still dominant, but the growth of market demand assumes increasing relative importance.

1931—1952: (Although this period is not covered by this paper, its major outlines may be traced). Output recovers to higher peak at end of Great Depression, but this was the high-water mark. Demand now dominates output about completely, with no significant new investment or cost-reducing innovations. Market structure is unaltered, with little or no change in the relative importance of the firms making up the industry.

Note on Sources Used.

Objections may be raised to the narrow research base of this paper. The writer has examined all the major printed sources on the period covered, such as Scharling & Falbe-Hansen *(Danmarks Statistik)*, Samsoe *(Die Industrialisierung Dänemarks)*, and Warming's *Danmarks Statistik*, 1914. Also examined were all issues of the *Nationaløkonomisk Tidsskrift* from 1870 to 1930, and official State statistics such as the *Erhvervstællinger* of 1896, 1907, and 1914, trade and shipping annual reports from 1853 to the present, and *Statistiske Meddelelser* reports from 1900 on. Nothing was found that the jubilee reports and annual corporation reports did not have in greater detail. Accordingly, the decision was made to work these sources intensively, adding the *Industriberetningerne* after their first appearance in 1906.

It would have been extremely desirable to go back to original sources such as newspapers and archives, but this was prevented by lack of time. This material may supply answers to questions inadequately treated by this paper because of deficiencies in the material consulted. Chief among these questions are the training of the labor force of the industry in the critical years 1850—1875, conditions surrounding the entrance of the provincial firms from 1916 to 1919, and the shaping of firm policy at Burmeister & Wain during the gestation of the motor-ship innovation.

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