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REAL CAPITAL AND ECONOMIC GROWTH IN NORWAY 1900–56

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INTRODUCTION

THE main purpose of this article is to present a review of the growth of real capital in Norway since the turn of the century. Attention has also been devoted to the relationship between the growth of real capital, employment, and net national product, however.[1]

In Section I some of the fundamental problems involved in computations of the value of the real capital are discussed. Attention is drawn to some of the defects and limitations which often are attached to estimates of the real capital stocks. Section II gives a description of the main features of the methods which have been applied for the Norwegian computations. Section III contains a summary of the principal results of the real capital computations. A more detailed statement of results is given in the Appendix. The last two sections comprise a closer analysis of the figures derived. Section IV is devoted to an analysis of the variations in the marginal capital–output ratio since 1900, with special emphasis on the remarkable post-war trend. Since 1948 the marginal capital–output ratio has been of the order of magnitude 5:1 as against 3:1 in earlier periods. In Section V it is pointed out that this may be explained by a production function of the Cobb–Douglas type with a trend component.

I. *DEFINITION AND VALUATION PROBLEMS*

In computations of the value of the stocks of real capital there are two vital questions which must be decided. The first is the question of defining the real objects one wants to include in the term real capital. The second, and far more difficult, problem consists in selecting a system of weights ('prices') which can be used in the aggregation of highly divergent real objects on the basis of a common unit of measurement.

[1] The work on this study has been carried out with the financial assistance of the Social Science Research Council.

The capital concept

In this study the concept of real capital is given a somewhat narrow scope. It embraces *all man-made durable real objects in private and public enterprises, including dwellings, and buildings and constructions of general government with the exception of military installations.* Durables are all real objects with a life expectancy of one year or more. Inventories, livestock, land, standing forests, and real objects in the hands of consumers have been excluded from the real capital concept, mainly because statistical sources do not permit annual estimates of these items to be made with any accuracy. The reader should bear this in mind when reading the analytical sections of the paper.

In order to permit some comparisons of the Norwegian figures with figures of other countries, rough estimates of the omitted items have been attempted for one single year, viz. for the end of 1953. These estimates, which are in current prices only, are included in Appendix, Table V. Apart from cars, the figures given do not include estimates of the value of durables in the hands of households, however.

The aggregation problem

To arrive at a convenient system of weights ('prices') for use in the aggregation of real objects of highly different nature it is necessary to operate on the basis of properties which the real objects have in common and which can be measured. Moreover, it is essential that the weight system be based on properties which are relevant from an economic-analytical point of view. However, we are immediately faced with the problem that there are almost no two real objects which are entirely identical in a technical sense. Even highly standardized categories of capital, such as automobiles, etc., will often have different technical qualities. In addition to these purely technical diversities, differences as regards total life and remaining life will make a comparison of various categories of real objects difficult. For these reasons one can hardly hope to arrive at a weight system on the direct basis of the technical properties of real objects.

There seems, however, to be two characteristics of capital objects as defined above which might serve as a basis for an economic measurement of the real capital. The first is that the production of capital objects entails a certain absorption of real resources (production costs). The second characteristic is that a certain production or earning capacity [1] is connected with the capital objects. These qualities seem to permit two different solutions to the aggregation problems. One method, which may be termed the *retrospective method*, implies looking back and using the costs of production as basis for the weight system. The second method, *the prospective method*, implies looking ahead and attempting to determine the weight system on the basis of the future earning capacity of the various real objects. Market prices, or substitutes for these in the absence of market prices, may be taken as an approximation to the latter weight system.

It is the first aggregation method, the retrospective, which has been applied in the Norwegian capital computations, and in the following section some features of this method will be analysed. The second method will also be discussed, however, as a comparison of the results derived from the two different methods is of interest.

The retrospective method

As has already been mentioned, this method implies that the costs of production for the various capital objects are taken as a starting-point. We are then faced with the choice between use of historical costs of capital and replacement costs in the valuation. For well-known reasons replacement costs are preferable. By the use of replacement costs a set of figures is derived for real capital in current value.

These figures will reflect the volume of real productive resources incorporated in the capital equipment as well as the current prices of these resources. To arrive at a volume concept for real capital (meaning by this the volume of accumulated productive resources absorbed) the current-value figures must be deflated with an appropriate cost index, that is an index reflecting the price trend for productive resources. To provide reliable expressions for such indices is not easy, but in principle it presents similar problems to those involved in other forms of price or cost indices.

Special problems arise in the estimation (in current value) of objects which are partly obsolete. To estimate all real objects,

[1] See Raymond W. Goldsmith, 'The Growth of Reproducible Wealth of the United States of America from 1805 to 1950', *Income and Wealth, Series II*, p. 249.

old as well as new, at full replacement cost would be tantamount to giving partly obsolete objects the same weight as completely new objects of the same category. The only way to avoid this is to base the valuation of partly obsolete objects on depreciated replacement costs. There is the difficulty, however, that several depreciation methods are possible (linear, progressive, and degressive). The choice between these will affect the computation result and lead to capital concepts of somewhat different content. Within the retrospective method, therefore, a number of variants are possible, depending on the depreciation system used. The choice among these variants can be made on a conventional basis only.[1] In the Norwegian computations constant depreciation allowances have in principle been used, i.e. equally large depreciation allowances each year through the life of the capital objects (the 'straight-line method').[2]

At a given time there will always be some real objects in use which have been rendered obsolete by technological and economic development, so that there can be no question of replacing them with identical units. For such objects it seems reasonable to base the estimates on the replacement costs of real objects by which the obsolete objects may be replaced, with proper adjustments for differences in the potential earning capacity of the two types of capital objects.

The prospective method

Under *the prospective method* the value of the capital items should reflect their future earning capacity. This must be determined on the basis of the future input and output flows which are associated with the different items. If we regard the prices of the various input and output categories and the discounting factors as given quantities at all times, and the future

[1] From the point of view of the individual company it may seem reasonable to provide for depreciation so that the value of the capital objects decreases in step with their remaining earning capacity. If this principle is to be strictly applied, it would be necessary to know the development over time of the output and input factors connected with the various capital objects. In practice, one will have to be content with more or less satisfactory approximations. *Stuvel* has pointed to linearly decreasing depreciation as a possible method. See G. Stuvel, 'The Estimation of Capital Consumption in National Accounting', *Review of Economic Studies*, 1955–56, Vol. XXIII (3), No. 62, pp. 183–185. Provided that the time function for the earning capacity of the capital objects decreases parabolically over the period, this method will be in agreement with the principle mentioned above. If, on the other hand, the earning capacity decreases linearly over the life period, the straight-line procedure will produce the desired result.

[2] Actually this principle may not always be fulfilled, cf. p. 90.

input and output flows are known, the earning capacity of the different capital items may in principle be estimated.

When the prospective method is used, one would in practice base the valuation on the market prices of the capital items, since as these can be taken as approximate expression of their earning capacity. Problems arise for the (quite numerous) categories of capital objects which are not usually sold in the market. In such cases one will have to guess what the market prices would have been if a market had existed. Another point in the prospective method is that no fundamental problems arise in the valuation of partly outworn capital objects, or objects which have been rendered obsolete by the technological and economic developments. The earning capacity or market prices give us the solution directly in both cases.

To arrive at figures for the value of the real capital measured in fixed prices under the prospective method one should in principle take the starting-point in a set of given (fixed) prices on all input and output factors and a set of discounting factors. In practice, the usual procedure is to deflate the figures in current prices by price indices designed to reflect the price trend for capital objects with a given potential earning capacity.

Comparison of the two methods

There is reason to believe that the results obtained under the two methods, in so far as the value of capital in terms of current prices is concerned, will not show very large deviations. The reason is that in most cases the market prices of capital goods are not likely to deviate much from their (depreciated) replacement costs as calculated by any standard method of depreciation under the retrospective method. It is obvious, for example, that the market price of new capital equipment cannot be far from its costs of production. But for partly obsolete objects, market prices may also be assumed to be fairly close, on an average, to depreciated replacement costs. This will be the case if and when the depreciation method actually used approximates, on an average, to the falling earning capacity of capital goods with increasing age.[1] With most of the standard depreciations methods discussed above this may not be too far from the truth.

For the value of capital in terms of *fixed* prices, on the other hand, the two methods will usually produce different results.

[1] See Raymond W. Goldsmith, *loc. cit.*, p. 251.

This is a consequence of the different meaning of the price-change concept in the two valuation methods. Under the *retrospective method* a series of figures for the value of the real capital in terms of fixed prices will reflect the quantity of productive resources which are incorporated in the capital equipment at various times. But the figures are not supposed to be influenced by the fact that as a result of increased technological knowledge it has gradually become possible to combine these productive resources in a more effective technique. Under the *prospective method*, on the other hand, one tries to compute figures in fixed prices which take into account both the increase in the volume of incorporated productive resources and improvements in technique. For here one uses price indices for capital objects which as far as possible are equal from a technological efficiency viewpoint. It is reasonable to assume that gradually increasing technological knowledge will make it possible to produce more effective capital objects with given investment of productive resources. It is to be expected, therefore, that the real capital volume will show a sharper increase over a period if the computations are performed under the *prospective valuation method* than if they are based on the *retrospective method*.

The choice between the two evaluation methods also depends on the objective of the computations. If the purpose is to study the role of capital as a factor of production, the *prospective method* may seem preferable. Volume figures for the capital computed on the basis of this method will, as pointed out above, also reflect improvements in the productive capacity of the capital as a result of more effective technique. That will not be the case to the same extent with volume figures computed under the *retrospective method*. This point is of significance if we want to use figures for the real capital in a production function to 'explain' the production trend over a lengthy period. If in this case we use capital data computed under the *retrospective method* we must include in the production function a special variable in order to allow for the effects of the gradual change in the technological level.[1]

[1] When real capital is to be used as explanatory variable in a production function there may be reason to question both of the valuation methods mentioned here. Under both methods partly obsolete capital objects will be given a substantially lower value than corresponding new objects, on the assumption that they have a lower *remaining* production capacity. But this probably does not give

If the primary purpose of the capital computations is regarded as part of the work on what Ingvar Ohlsson [1] terms 'statement of results' the *retrospective method* seems to be the most satisfactory. Two arguments may, as far as we can see, be raised in support of this:

(i) It is natural to require of our capital data that they (in terms of fixed prices) be consistent with the national account figures (also expressed in fixed prices), i.e. that the capital growth over a period according to the capital estimates shall equal the accumulated net investments over that period according to the national accounts. But in a national accounting system, prepared for the purpose of measuring 'economic results', net investments have to be estimated so as to give a measure of the volume of the productive resources which have been used to increase the capital of the society. It follows that in the capital computations also we must regard the capital as 'accumulated productive resources', which means that the *retrospective method* must be applied. Provided that the same principles are applied in the estimation of the depreciation in both cases, this will result in capital stock figures at constant prices which are consistent with the current national accounting figures at constant prices.

(ii) In analysing economic results it is often necessary to use stock data and current data together, for example, in analyses where the capital is regarded as the accumulated result of the production of earlier periods. It is therefore desirable that the two sets of data be based on identical valuation principles, i.e. that the capital data, like the current data, are computed on the basis of the production costs of the commodities.

In both cases a deeper reason for the choice of valuation principle lies in the fact that the production costs express a fundamental transformation relationship between the objects, as they

a satisfactory expression of the relation between the *current* production capacity of old and new equipment, for example, a ten-year-old railroad car in the short run may be of as good service as a completely new one. It is presumed that this factor may be disturbing for short-term analyses, where the age structure of the capital may vary appreciably, and where changes in the value of the capital therefore will not always provide a good measure for the changes in its production capacity.

[1] Ingvar Ohlsson, *On National Accounting*, Stockholm, 1953.

approximately measure the quantities of productive resources which are incorporated in them.

II. COMPUTATION METHODS

In this section a brief outline will be given of the computation methods of the Norwegian capital estimates. The employment data which are used in sections III–V will also be described in some detail.

Capital computations

Figures for the real capital volume have been computed on an annual basis for the period 1900–55 with the exception of the war years 1940–45. For all years the real capital has been classified into the following four groups: buildings and constructions in private and public enterprises; buildings and constructions of general government; ships and boats; machinery, tools, and transportation equipment excluding ships. More detailed data by industry as well as by type are available for three years, viz. the years 1900, 1939, and 1953. All results are expressed in 1938 prices.

The computations have been performed in three steps, or by three different types of computations. Step (1) was to determine figures for gross investment, measured in 1938 prices, for each year in the period under review and for each capital group. Step (2) consisted in direct and detailed computations of the value of the real capital stocks (in 1938 prices) at a few bench-mark points, namely at the end of the years 1899, 1920, 1939, and 1953. Steps (1) and (2) together gave the data required to compute (separately for each capital group) the total net investments and the total capital consumption within each of the periods 1900–20, 1921–39. In step (3) these preliminary results were used to compute annual figures for the capital consumption in each capital group, also in terms of 1938 prices. Together with the annual gross investment figures (step (1)) and directly computed capital data for bench-mark years (step (2)), this permitted a simple determination of the annual stock data. The computations at the various steps have been described in further detail in the following.

It is characteristic of the computation method applied that it is based on computations of gross investments for all years and independently derived estimates of capital stocks for bench-mark years, and that the results of these computations are controlled against each other by studying the implications they entail for the development of capital consumption. The capital-consumption data are useful *per se*, and will be used in the Norwegian national accounts.[1]

Step (1): Computation of annual gross investment figures

The gross investment data used in this study have been taken from earlier published national accounting data and are mainly estimated by the commodity-flow approach, i.e. on the basis of import statistics and Norwegian production of capital goods. Further details on the computations in fixed and current prices may be obtained from official publications.[2] The lack of gross investment data for the years 1940–45 is the main reason why this article contains no capital-stock figures for these years.

Step (2): Capital computations for bench-mark years

For no year are census results available which permit a computation of capital stocks based on complete and homogeneous material. The computations for bench-mark years made for this study are therefore based on data collected from highly variable sources, often supplemented with approximate corrections and estimates. As a general rule, total figures must be presumed subject to smaller relative margins of error than the more detailed specifications presented.

For the years 1899, 1939, and 1953 the capital-stock figures are based on detailed computations for each single group of capital objects, made separately for each individual industry. The computations for 1920 are more summary, and their main purpose has been to provide some basis for judging whether capital consumption over the fifty-year period have developed proportionally with the capital volume (see p. 90 below). The

[1] In our opinion it would be difficult to find a better method for computation of the level of capital consumption, as it guarantees that the national accounting data on capital consumption will be consistent with the gross investment data and with the best estimates that can be made of the size of the capital stocks at different points of time. The need for capital consumption data for the national account was, as a matter of fact, one of the main reasons for undertaking this study.

[2] Organization of European Economic Co-operation, *National Accounts Studies – Norway*, Paris, 1953, pp. 100–101. Central Bureau of Statistics of Norway, *National Accounts 1900–1929* (NOS. XI. 143), pp. 10–13, *National Accounts 1930–1939 and 1946–1951* (NOS. XI. 109), pp. 50–51, and *National Accounts 1938 and 1948–1953* (NOS. XI. 185), pp. 37–38.

nature of the statistical sources used in the direct capital computations vary from industry to industry and from capital object to capital object.

For some categories of capital it has been possible to base the computations on direct volume data and production costs data, sometimes supplemented by data on the age structure of capital. Dwellings, ships and boats, automobiles, roads and railroads are examples of groups of capital objects for which we have been able to make direct use of volume and cost data.

For other categories of capital objects the computations are based on value data, generally measured in current prices. These data are sometimes fire-insurance values, in other cases book values. The book values represent in some cases depreciated capital values, in others cumulated historical costs before depreciation. Manufacturing and mining are examples of industries where data on fire-insurance values have been available. For post, telegraph and telephone, and for railway and tramway rolling stock the computations are based on book values.

For the components of the capital equipment where computations are based on value data in current prices one of the difficult problems has been the conversion from current prices into 1938 prices. The price indices used for these computations have in most cases been those used for the fixed-price estimates for gross investment in the national accounts for the period 1900–55.

Step (3): Computation of annual capital consumption data

With the aid of data from step (1) and step (2) the sum total of the capital consumption over a period of years can be determined.[1] In our case the computations provide figures for the total capital consumption for the period 1900–39 and for the two sub-periods 1900–20 and 1921–39, separately for each of the four object groups of real capital discussed in paragraph 20. (A computation of capital consumption by industry is not possible, however, as gross investment data by industry are not available for the whole period 1900–39.)

[1] We have $D_{t/t+\theta} = J_{t/t+\theta} - (C_{t+\theta} - C_t)$, where $D_{t/t+\theta}$ and $J_{t/t+\theta}$ denote capital consumption and gross investment respectively in the period from t to $t + \theta$ and $C_{t+\theta}$ and C_t the size of the real capital at the end of the period and at the beginning of the period. $D_{t/t+\theta}$ can be set as balance when the right hand elements are known.

The next problem is to distribute the total of capital consumption thus estimated over the different years in the period. This can be done by assuming that each year's capital consumption varies in a given way with the depreciated value of the real capital at the beginning of the year (both expressed in 1938 prices).[1] The simplest assumption would be to assume that capital consumption throughout the period has been proportional to the capital value. However, the computations for the two sub-periods 1900–20 and 1921–39 indicate that the capital-consumption ratios (capital consumption in 1938 prices as a percentage of the real capital measured in 1938 prices) must have been higher after 1920 than before 1920 for all categories of capital objects. It seems natural to deduce from this that in the course of the period 1900–39 a gradual shortening of the 'normal' life of capital has taken place. We have therefore based our computations on the assumption that capital consumption as a percentage of the capital value has shown a linear rise over this period. In other words, we have assumed, for each kind of capital, that the capital consumption ratio p_t can be written

$$p_t = a + bt$$

where a and b are positive constants, and where t denotes the time. The magnitude t may assume values from 0 (in 1900) to 39 (in 1939).

We now have sufficient data to be able to determine the absolute magnitude of the capital consumption in each year and the capital at the beginning of each year. The procedure is as follows: It is possible to determine the constants a and b for each group of capital through the figures derived for the value of the real capital at the end of 1899, 1920, and 1939 and the capital consumption figures for the sub-periods 1900–20 and 1921–39. The capital-consumption ratios for each year then follow automatically from the above formula. But when the capital-consumption ratios are known and data are available for gross in-

[1] The straight-line method which was chosen for the present study requires the value of capital as new to be used as a basis for this distribution. Unfortunately, this could not be done for lack of data, and the method actually used must be viewed as an approximation to the former. It is justified in that the two methods will give identical results when applied to a stock of capital goods with a given age distribution. However, since the distribution by age of the various categories of capital cannot be expected to have remained constant over the period in question, the results obtained must be assumed to deviate somewhat from the values one should have got, had the straight-line method been strictly applicable.

vestments in each year it is a simple matter to compute annual capital-stock figures and annual capital-consumption data, starting from a direct estimate of the capital stock of one year, say the end of 1899.[1]

The computations for the post-war period are based on a form of extrapolation of bench-mark data for 1953. It is assumed that the capital-consumption percentages for the years 1946–56 can be determined through the same formula (with the same constants) as for 1900–39. Annual capital-consumption figures and stock figures for the real capital have then been computed as before, on the basis of these depreciation ratios, the already available annual investment figures, and the direct estimate of the capital stock in 1953.

Computation of employment data

For the period 1930–56, with the exception of the war years, annual employment figures in terms of man-years have been published in the official national accounts.[2] These figures are based on detailed computations for individual industries.

The employment data used in this article for the years prior to 1930 have a far weaker statistical foundation. They are not based on detailed computations for each individual industry. The data have been derived largely by backward extrapolation of the national accounting total for man-years in 1930. In the extrapolation the size of the working population, estimated on the basis of population censuses for 1900, 1910, 1920, and 1930, has been used as an indicator. A correction has been attempted for variations in unemployment, however. These corrections are based on data on unemployment among trade-union members.[3]

III. MAIN FINDINGS

The real capital data derived from the computations are presented in detail in the Appendix and in excerpts in Tables I–III below. Some comments on the figures are given in the following paragraphs.

[1] Capital consumption in 1900 is derived by applying the capital-consumption ratio for 1900 to the estimate of the real capital at the end of 1899. When gross investments for 1900 are known the size of the capital at the end of 1900 follows from this. With this as basis, the capital consumption for 1901 and the capital at the end of 1901 can be determined, and so on.

[2] See *National Accounts 1930–1939 and 1946–1951* (NOS. XI. 109) and *National Accounts 1938 and 1948–1953* (NOS. XI. 185), table 39.

[3] See *Statistiske oversikter 1948* (NOS. X. 178).

The growth of the total volume of real capital

The volume of capital has grown continuously since 1900, apart from the war period 1940–45. On the basis 1900 = 100, the volume of capital at the end of 1955 was 390 (Table I). This implies an average rate of growth of 2·4 per cent per annum.

TABLE I

Real Capital[1] *by Type at the End of Selected Years*

Year	Value of Fixed Real Capital	As Percentage Value Fixed Real Capital at 1938 Prices				Index of Total Fixed Real Capital 1900 = 100
	Million krona in 1938 prices	Buildings and Constructions of General Government	Buildings and Constructions of Enterprises	Machinery and Transportation Equipment Excl. Ships and Boats	Ships and Boats	
1899	7,250	14·5	73·5	6·8	5·2	100
1905	8,075	14·3	72·3	7·7	5·7	111
1910	8,961	13·4	71·5	9·1	6·0	124
1915	10,550	12·7	70·7	10·2	6·4	146
1920	12,203	11·9	72·0	10·5	5·6	168
1925	13,351	13·2	70·9	10·1	5·8	184
1930	14,990	13·2	68·2	10·5	8·1	207
1935	16,319	13·6	68·4	10·9	7·1	225
1939	18,874	13·2	66·4	12·5	7·9	260
1945	16,461	15·5	69·4	10·1	5·0	227
1950	21,578	14·1	64·9	12·7	8·3	298
1955	28,284	13·0	62·3	16·7	8·0	390

The rate of growth of capital shows large variations as between quinquennia (Table II). The most rapid growth in real capital before the last world war occurred between 1910 and 1920 and in the years 1935–39. In both these periods the rate of growth was well over 3 per cent per annum. The growth was notably slow in the five-year periods 1900–5 (1·7 per cent per annum), 1920–25 (1·8 per cent), and 1930–35 (1·7 per cent).

Between 1939 and 1945 there was a decline in total real capital of some 13 per cent.[2] The decline was due not so much to the

[1] Structures and equipment only.

[2] This is a somewhat lower figure than that computed by the Central Bureau of Statistics in 1946. The Bureau at that time arrived at an estimated capital reduction of 18·5 per cent, but this estimate included inventories, personal furniture, and movables, where the capital reduction was particularly large (Statistisk Sentralbyrå, *Nasjonalinntekten i Norge 1935–1943* (NOS. X. 102), p. 159).

decrease in the number of capital objects as to the fact that the average remaining life of capital dropped sharply. This fact must be borne in mind in considering changes in the real capital volume in relation to the net national product (the capital–output ratio) from 1939 up to the first post-war years.[1]

TABLE II

Growth of Real Capital[2] by Groups. Average Rates of Growth for Five-year Periods

Period	Increase in Real Capital, Absolute Figure	As Percentages of Increase in Real Capital			Average Rate of Growth, All Groups
	Million krona in 1938 prices	Buildings and Constructions	Machinery and Transportation Equipment, Excl. Ships	Ships and Boats	Per cent per annum
1900–05	658	71·0	17·8	11·2	1·7
1905–10	886	70·0	21·6	8·4	2·1
1910–15	1,589	74·5	16·6	8·9	3·3
1915–20	1,653	87·1	12·7	0·2	2·9
1920–25	1,148	87·5	4·7	7·9	1·8
1925–30	1,639	59·1	13·9	26·9	2·3
1930–35	1,329	88·0	15·3	−3·3	1·7
1935–39	2,555	64·2	23·0	12·8	3·7
1939–45	−2,413	43·6	28·5	27·9	−2·3
1945–50	5,117	60·0	20·9	19·1	5·6
1950–55	6,706	64·0	29·3	6·7	5·6

After the last world war the growth of real capital has been considerably stronger than for any other period in this century, viz. 5·6 per cent per annum on the average for the period 1945–55. It is remarkable that in spite of the capital reduction during the War we find the same rate of growth for the period 1939–55 as a whole as for the period 1900–39. The growth of capital in the years 1946–55 has, in other words, been sufficiently rapid to offset entirely the setback due to World War II.

Capital structure by type

The growth has not been equally strong for all groups of real capital. Estimated for the period 1900–55 as a whole, we find average rates of growth of 4·2 per cent per annum for machinery

[1] See p. 102.

[2] Structures and equipment only.

and transportation equipment (ships excluded), 3·3 per cent per annum for ships and boats, and 2·2 per cent per annum for buildings and constructions. To some extent the figures reflect the extensive mechanization which has taken place over the period in question

As a result of this there has been a marked change in the composition of capital. Buildings and constructions still represent the largest group, but have dropped from 88·0 per cent of total real capital (measured in 1938 prices) in 1900 to 75·3 per cent in 1955. In the same period the ratio for machines and transportation equipment (ships excluded) increased from 6·8 to 16·7 per cent and for ships and boats from 5·2 to 8·0 per cent.

The relative decline in the building and construction capital has been a stable feature in the development through the whole century. Only during the two world wars has there been a temporary increase in the relative importance of this capital group, and exclusively because the merchant fleet was substantially reduced through war losses.

The growing relative importance of machinery and transportation equipment (ships excluded) has also been a comparatively stable feature of the picture. Apart from a time of relative stagnation at the beginning of the twenties, it is only for the war years 1939–45 that the ratio for machinery and transportation equipment shows decline.

For ships and boats the trend has been more irregular. In this group we find periods of progress as well as periods of decline. The progress was most pronounced in the periods 1900–16, 1924–31, and 1945–55. There was an absolute decline towards the end of, and immediately after, World War I and in the period 1931–34.

Government building and construction measured as a proportion of total real capital has shown a slight downward trend through the period. The growth of real capital in this group has nevertheless been somewhat more rapid than for building and construction as a whole.

Real capital by industries

As pointed out earlier, it has not been possible to compute annual figures for real capital by industries, as pre-1930 gross investment data by industry are not available. Directly computed capital figures for the years 1900, 1939, and 1953, however, show the main lines of the development.

There has been increase in real capital within all industries, but the growth has been somewhat varied. The growth has been relatively weak within agriculture and forestry and housing, and particularly strong for mining, manufacturing, electricity development, and shipping.

TABLE III

Real Capital[1] *by Main Industry Groups in 1900, 1939, and 1953*

Industry Group	Absolute Figures: Million kroner in 1938 prices			Percentage Distribution		
	1900	1939	1953	1900	1939	1953
Agriculture and forestry	1,112	2,090	2,382	15·3	11·1	9·4
Fishing and whaling	113	352	385	1·6	1·9	1·5
Mining and manufacturing	555	2,552	4,067	7·6	13·5	16·0
Electricity and gas	30	1,100	2,083	0·4	5·8	8·2
Dwellings	3,062	6,200	7,289	42·3	32·8	28·7
Sea transport	340	1,389	1,932	4·7	7·4	7·6
Other transport	446	1,418	2,038	6·1	7·5	8·0
Merchandise trade and services	540	1,281	1,815	7·5	6·7	7·1
General government	1,052	2,492	3,444	14·5	13·3	13·5
Of which: Highways and bridges	540	1,320	1,726	7·4	7·0	6·8
Total	7,250	18,874	25,435	100·0	100·0	100·0

The trend is reflected in the individual industries' ratio of the total real capital. For agriculture and forestry this ratio dropped from 15·3 per cent in 1900 to 9·4 per cent in 1953. (It should be observed that the figures do not include land and ground, livestock and standing forests. The relative decline would probably have been even bigger if these items had been included.) For housing there is a decrease from 42·3 per cent in 1900 to 28·7 per cent in 1953, or relatively a slightly weaker decrease than for agriculture and forestry. For all other sectors the ratio shows a rise or standstill.

The increase is particularly marked for electricity, mining, and manufacturing. For these sectors as a whole the ratio has trebled between 1900 and 1953, namely from 8 to 24 per cent. These

[1] Structures and equipment only.

industries accounted for almost one-third of the total net investment in the period. The growth has been most rapid in electricity, where the ratio advanced from 0·4 per cent in 1900 to 5·8 per cent in 1939 and to 8·2 per cent at the end of 1953.

Sea transport has also increased its ratio of the total real capital quite appreciably. The ratio rose from not quite 5 per cent in 1900 to about 7·5 per cent in 1939, a level reached again in 1953, when the effects of the tonnage loss during the War had been overcome.

The ratio has increased for other transport as well, viz. from 6·1 to 8·0 per cent. The rise is small, however (from 13·5 to 14·8 per cent), if capital of general government in highways and highway bridges is included in this group. The entire growth relates to highway and air transport, and post, telephone, and telegraph. The railroad ratio of the total real capital has remained unchanged.

For service trades other than transport the ratio has dropped. For machinery and transport, however, there is also a strong relative rise.

The data presented above on the composition of the real capital by industry and object do not alter the picture suggested by other evidence on economic developments in this century. It confirms the view that the most marked feature of the picture is the relative decline of agriculture, the rapid relative growth of manufacturing, and the exploitation of water-power as a source of energy. The relative expansion in sea transport and the increasing role of machinery and transport equipment compared with building capital are also points worth noting.

Relation between real capital, employment, and production

In the course of the fifty-six years under review the real capital in Norway has almost quadrupled. The average rate of growth has been 2·4 per cent per annum. In *per capita* terms the corresponding rate of growth has been about 1·6 per cent per annum. The tables give a strong impression of the extent to which the wealth of a modern society is a result of the efforts of the latest generation. About three-quarters of the real capital in existence in Norway today has been created since the turn of the century, only one-quarter is a heritage from earlier times.

The growth in employment has been considerably slower. The number of man-years in 1956 was only about 60 per cent higher than in 1900, corresponding to an average annual rate of growth of some 0·8 per cent. This, of course, means that production has become more 'capital-intensive'. In 1956 there was over 2·5 times as much capital behind each worker as at the turn of the century. The growth of real capital per man-year has been a relatively stable feature since 1900. It is only during the last world war and exceptionally in the 1920s that employment has risen more rapidly than the capital, so that the capital–labour ratio has dropped.

Production has risen more rapidly than both capital and employment. With 1900 = 100 the net national product in 1955 was 457. This corresponds to an average rate of growth of 2·8 per cent per annum, or 2·0 per cent if the growth is calculated per man-year and 2·0 per cent if estimated *per capita*. Thus, while production has undoubtedly become more 'capital-intensive' in the sense that the capital–labour ratio has risen, it has not also become more 'round-about', if by that we mean that the real capital represents more years of 'accumulated production' now than half a century ago. On the contrary, while the real capital expressed in fixed prices in 1900 represented about four years' national product, the average capital–output ratio in 1956 had dropped to approx. 3·3.

TABLE IV

Average Rates of Growth for Net National Product, Real Capital,[1] *and Employment in Selected Periods*

Period	Average Percentage Growth per Annum in Real Capital Volume	Average Percentage Growth Per Annum in Number of Man-years	Average Rates of Growth for Real Capital Volume per Man-year	Average Rates of Growth for Net National Product
1900–05	1·7	0·4	1·3	0·4
1905–10	2·1	0·8	1·3	3·5
1910–15	3·3	1·3	2·0	4·3
1915–20	2·9	1·6	1·3	3·1
1920–25	1·8	−0·6	2·5	0·4
1925–30	2·3	0·4	2·0	5·3
1930–35	1·7	0·9	0·8	1·3
1935–39	3·7	2·3	1·3	4·6
1930–46	−1·4	0·4	−2·0	0·5
1946–48	6·0	2·7	3·3	8·7
1948–51	5·5	0·9	4·7	3·7
1951–55	5·6	0·4	5·1	3·3

[1] Structures and equipment only.

The growth in the period 1900–56 has by no means been steady. Table IV indicates that there have been sharp fluctuations in the rates of growth of both real capital, employment, and national product. The table further shows that there is a comparatively high degree of co-variation between the three series. On the whole, we find that periods of rapid capital increase have also been periods of rapid growth in employment, and these are naturally also the periods when the rise in production has been greatest. Particularly striking is the co-variation between the rate of growth of real capital and the rate of growth of national product. It is worth noting, however, that the period following the last war is different both in this and other respects. One point often made is, for example, that the growth in the national product after 1948 does not seem to be in any reasonable proportion to the exceptionally rapid growth in the real capital in these years. In the remainder of this paper the co-variation between capital, employment, and production will be subjected to closer analysis.

IV. THE CAPITAL–OUTPUT RATIO

The idea of a constant marginal capital–output ratio

Studies from several countries, particularly the United States and Great Britain, have shown that a remarkable stability can be found in historical data in the relationship between the volume of capital and the volume of national product, totally or marginally. Sometimes this stability is interpreted as an economic law, from which the impression is gained that the size of production is determined by the volume of capital alone. Economic growth models of the Domar–Harrod type are examples of models which characteristically assume a constant marginal capital–output ratio.

It should be stressed, however, that *a priori* we have no reason to expect such a simple connection between increments in real capital and national product. On the contrary, production theory suggests that the marginal productivity of capital is not likely to be a constant, but a quantity which will vary with the size of the capital itself, as well as with employment and the technological level. Consequently, we cannot expect that a given increase of real capital will always lead to a proportionate increase of the national product, irrespective of what is happening to employment and to technology. Yet another argument may be added. Various kinds of capital will as a rule have different marginal productivity from a social point of view. The effects on the national product of a particular capital increase is therefore not independent of the 'mix' in which the capital increase takes place. 100 million kroner more invested in highways, for example, might lead to a different increase in the national product than the same amount invested in new housing.[1]

Against this background we shall in the following pages consider the actual trends in real capital and national product in Norway for the period after 1900. The main features are

TABLE V

Increments in Real Capital[2] *and Net National Product for Bench-Mark Periods*

(Figures in 1938 prices)

Period	Real Capital Increment	Net National Product Increment	Marginal Capital–Output Ratio
	Million kroner	Million kroner	1 ÷ 2 = 3
	1	2	3
1900–16 . .	3,300	1,049	3·15
1916–30 . .	3,950	1,326	2·99
1930–37 . .	2,351	816	2·88
1939–56 . .	10,136	3,199	3·17
1900–56 . .	21,078	6,731	3·13
1946–51 . .	5,126	1,767	2·90
1947–51 . .	4,430	1,011	4·38
1951–56 . .	6,741	1,230	5·48

illustrated in Graph 1 below, where correlated values of national product and real capital have been drawn for each year except the war years 1940–45 (the fine line). The graph should be studied together with Table V, where the increment in real capital and national product is shown for bench-mark periods.

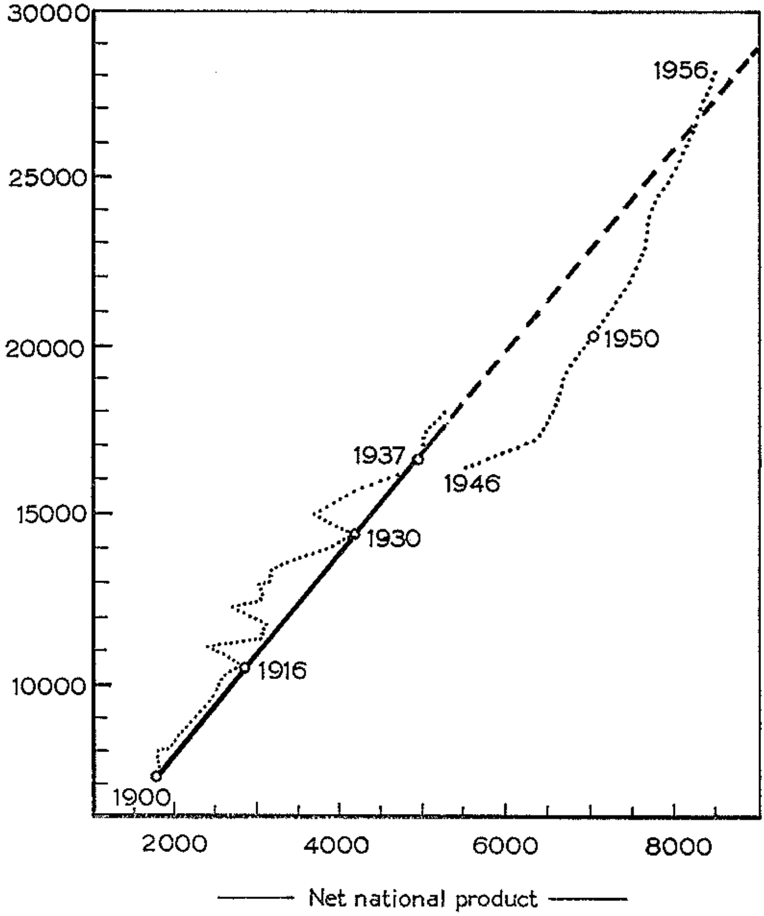
The period 1900–39

For the period before the last world war real capital and national product have risen largely in step. This is particularly clear if we focus our attention on boom years in the period

[1] For an elaboration of this reasoning see Odd Aukrust, 'Effect of Investments on National Product', *Statsøkon. Tidsskrift*, 1957, No. 2.

[2] Structures and equipment only.

Growth of real capital and net national product 1900-39 and 1946-56



(which in Norway were 1900, 1916, 1930, and 1937) and disregard intermediate years when production capacity was not fully utilized. By and large, an increase in real capital of 300 million kroner (in fixed prices) has resulted in a rise in the annual national product of 100 million kroner, i.e. the marginal capital coefficient has been 3·0 for the period as a whole. This is shown by the fitted, fully drawn-in straight line in the graph.[1]

The graph further indicates that this ratio has kept remarkably constant in the different cyclical periods, measured from peak to peak. Table V shows that the marginal capital coefficient for the period 1900–16, was 3·15, for the period 1916–30, 2·99, and for 1930–37, 2·88. For the period 1930–39 it was 3·19.

But the graph also indicates that there are substantial year-to-year deviations from the straight line. It is justified to conclude from it that the physical production potentials were not fully utilized in inter-peak periods. The area above the fitted line thus roughly measures the 'loss in production' resulting from insufficient aggregate demand in the inter-war period. It is necessary to add, however, that not even in 1930 and 1937 was actual production capacity fully utilized, as there was extensive unemployment in both these years.

The period 1946–56

For the period following World War II the historical line has a course which on several points deviates radically from the trend before 1939. True, the marginal capital–output ratio for the whole period 1939–56 (3·17) does not differ much from the ratio derived for the pre-war period. But within this period the ratios shows substantial variations. Altogether, there are several features of the trend which seem peculiar: (i) There is a notable shift in the historical line between 1939 and 1945. Already in 1946 production was well above the pre-war level, despite the fact that real capital was considerably lower than in 1939. (ii) At the same time the national product showed a very rapid growth in the first two post-war years. For these years we find considerably lower values both for the average and the

[1] The line is a regression line for real capital (C_+) with respect to national product (Y_+), estimated on the basis of observations for 1900, 1916, 1929, and 1937. The formula of the line is $C_t = 3{\cdot}00\ Y_t + 1{,}840$.

marginal capital–output ratio than those we know from the pre-war years. (iii) A change occurs in 1948. From then on the marginal capital–output ratio has been decidedly higher than in the inter-war period and at the same time increasing. It was 4·38 for the years 1947–51 and 5·48 for the years 1951–56, or 4·99 for the whole period 1947–56.

How are these facts to be explained? The most simple explanation is perhaps to regard the course of the historical line in the early post-war years as an 'accidental and transitory' deviation to the right from the underlying long-run trend, followed by a normalization, e.g. as a consequence of variations in total demand. This is tantamount to acceptance of the hypothesis that the long-run marginal capital–output ratio is a constant and suggests that for coming years we must again expect to find the value of the marginal capital–output ratio at around 3·0.

As we have pointed out on p. 98, however, there is no reason to expect the marginal capital–output ratio to remain stable over time, rather the contrary. In particular, we have to assume that this ratio will itself be a function of employment, volume of capital, and production technique. A more subtle explanation for the post-war trend than that suggested in the previous paragraph is therefore required.

The following factors provide an explanation for the shift in the historical line from 1939 to 1946: (i) Employment was somewhat higher in 1946 than in 1939. (ii) Parallel with the rise in employment there was an extensive shift of labour from sectors with low net product per man-year to sectors with high net product. (ii) It is probable that our capital figures, as computed, exaggerate the decrease during the War in the current production capacity of the capital.[1]

The low marginal capital–output ratio in the early post-war years can be plausibly explained as follows: (i) The capital increase in those years was accompanied by a very sharp rise in employment. (ii) The marginal productivity of capital was high, because the real capital volume per employed was lower than before the War. (iii) Simultaneously with the capital increase there was a rapid technological change. In 1946 the results of six to seven years of rapid development abroad were suddenly at our disposal.

It is more difficult to explain the high and rising capital–output

[1] Cf. p. 92.

ratio from 1948 onwards. It has been suggested that the investment structure may have had some effect, and that may be true. But the main factors appear to be the following: (i) The rate of increase in employment has been somewhat slower in 1948 than earlier in the century, and substantially slower than in the first two post-war years. (ii) Because of the high investment level in post-war years, real capital per employed has risen rapidly (from 12,000 1938 kroner in 1946 to 18,000 kroner in 1956). The marginal productivity of capital has therefore dropped. (iii) The decreasing demand pressure since 1950 has probably curbed the production increase. (This is the factor that was originally suggested above as the *only* explanation, but which we rejected as such.) (iv) Because the average age of the capital has been declining, its productivity has risen less than the capital volume, as measured in this study.

The explanation of the post-war development given in the preceding paragraphs contains quite different implications for the future than the simple explanation originally advanced. If we admit that the volume of production does not only depend on the volume of capital, but assume more complicated production functions, it cannot be taken for granted that the marginal capital–output ratio will drop again to its former level of about 3·0. On the contrary, it is quite possible that in the future we must again reckon with a ratio of the present order of 5·0 or higher. Whether the one or the other will be the case is a question of great importance for the future prospects of our economy. With our present net investment rate (15–18 per cent per annum) a marginal capital–output ratio of 5·0–6·0 corresponds to a rate of growth for the national product of 2·5–3·6 per cent per annum. A marginal capital–output ratio of 3·0 will with the same investments give a rate of growth of 5·0–6·0 per cent per annum. The difference is so great that further attempts to investigate the shape of the aggregate production function are well justified.

V. SOME EXPERIMENTS IN FITTING A PRODUCTION FUNCTION TO DATA

(a) *Selecting the form of the function*

Attempts to estimate relatively strongly aggregated production functions have frequently been made. The earliest and the majority of these experiments have concerned individual manufacturing groups or manufacturing in general,[1] but some have also been applied to agriculture.[2] A few studies have adopted production functions for the whole national economy.[3]

Most of these studies have used functions of the Cobb–Douglas type or variations of this. In its original form this was written as an exponential function of the type.

$$Y = AC^{\alpha}L^{\beta} \quad . \quad . \quad . \quad (1)$$

where the magnitudes A, α, and β are constants, and where Y, C, and L denote the production volume, input of capital, and labour respectively. In the early studies by Cobb and Douglas it was assumed that the sum total of the exponents α and β equalled 1 (which is tantamount to assuming that the production law has *pari-passu* character). The function above can then be written somewhat more simply, namely as

$$Y = AC^{\alpha}L^{1-\alpha} \quad . \quad . \quad . \quad (2)$$

where there are only two constants α and A. In later works efforts have also been made to estimate the constants α and β freely, i.e. assuming that the sum total does not necessarily equal 1.

The Cobb–Douglas function in its original form does not take into consideration changing techniques. This has been done in some later studies, where attempts have been made to allow for the effect of technological improvements by introducing a trend factor, while maintaining the general form of the Cobb–Douglas function. In his attempt to estimate a production function for the overall U.S. economy in the period 1921–41, Tint-

[1] The most well-known research works are perhaps those done by C. W. Cobb, P. H. Douglas, and a number of his collaborators. Cf. for instance C. W. Cobb and P. H. Douglas, 'A Theory of Production', *American Economic Review*, Vol. 18. Supplement 1928. P. H. Douglas, *The theory of Wages*, New York, 1934. M. L. Handsaker and P. H. Douglas, 'The Theory of Marginal Productivity Tested by Data for Manufacturing in Victoria', *The Quarterly Journal of Economics*, Vol. 52 (1937/38). G. T. Gunn and P. H. Douglas, 'Further Measurement of Marginal Productivity', *The Quarterly Journal of Economics*, Vol. 54 (1939/40). M. Bronfenbremer and P. H. Douglas, 'Cross-section Studies in the Cobb–Douglas Function', *The Journal of Political Economy*, Vol. 47 (1939). G. T. Gunn and P. H. Douglas, 'The Production Function for American Manufacturing in 1919', *The American Economic Review*, Vol. 31 (1941).

[2] G. Tinter, 'A Note on the Derivation of Production Functions from Farm Records', *Econometrica*, Vol. 12 (1944).

[3] G. Tintner, 'Some Applications of Multivariate Analysis to Economic Data', *Journal of the American Statistical Association*, Vol. 41 (1946), pp. 496–500. J. Tinbergen, 'Zur Theorie der langfristigen Wirtschaftsentwicklung', *Weltwirtschaftliches Archiv*, 1942, p. 509.

ner[1] used a relation which is linear in the logarithms to Y, C, L and in the variable time. Tinbergen's earlier work involved a production function of the type

$$Y = \epsilon^{t} C^{\alpha} L^{1-\alpha} \quad . \quad . \quad . \quad (3)$$

V. E. Smith [2] has tried to estimate the constants in a production function for the Canadian automobile industry in the period 1918–30 by the formula

$$Y = AC^{\alpha}L^{\beta}\,(10^{ht+gt^{2}}) \quad . \quad . \quad (4)$$

For our purpose it is natural to regard the net national product as a function of the production factors real capital, labour, and 'technique'. We shall assume that the shape of the functional relationship is such that the three factors of production enter into it symmetrically in the same manner as in production functions of the Cobb–Douglas type. The factor 'technique' is defined broadly so as to include the general level of technical knowledge, the efficiency of management and workers, the industrial structure, etc. So defined, the 'volume of technique' cannot be measured, however, and for our purpose we shall simply assume that it can be represented by an exponential function e^{ht}, where t denotes time and h the rate of growth of the 'volume of technique'. The plausibility of this assumption is, of course, debatable. It leads to the following formula for the production function of the overall economy

$$Y_t = AC^{\alpha}_{t}L^{\beta}_{t}\,e^{t\gamma} \text{ [3]} \quad . \quad . \quad . \quad (5)$$

which written in logarithmic form becomes

$$\log Y_t = \log A + \alpha \log C_t + \beta \log L_t + \gamma \log e{\cdot}t \quad (6)$$

Here Y_t is the net national product in year t measured in 1938 kroner, C_t the real capital volume at the end of year t also measured in 1938 kroner, L_t employment in year t measured by number of man-years, and t the time measured with 1925 as

[1] G. Tinter, *loc. cit.*

[2] *V. E. Smith*, 'Nonlinearity in the Relation between Input and Output: The Canadian Automobile Industry 1918–1930', *Econometrica*, Vol. 13, 1945.

[3] We have $Y_t = AC^{\alpha}{}_{t}\,L^{\beta}{}_{t}\,(e^{ht})^{\lambda}$, where λ denotes the elasticity of net product with respect to the 'volume of technique'. Inserting the letter γ for $h{\cdot}\lambda$ we get the expression in formula (5) above. The elasticity λ cannot be estimated separately, since we have no direct estimates of the 'volume of technique' or its rate of growth h. The rate of growth in production resulting from improvements in 'technique', in which we are primarily interested, can, however, be ascertained by the estimate of γ which measures the combined effect of both h and λ.

base year. A, α, β, and γ are constants, the numerical value of which can be estimated on the basis of the available data.

A structural relationship of this type cannot be expected to hold exactly. We therefore choose to give it a stochastic formulation:

$$\log Y_t = \log A + \alpha \log C_t + \beta \log L_t + \gamma \log e{\cdot}t + u_t \quad (7)$$

where u_t is a stochastic residual with expectation zero and variance $\gamma_u{}^2$. If we assume that the variables are observed without measurement errors and that C_t and L_t are non-stochastic variables, the parameters A, α, β, and γ can be estimated by minimizing the sum of the square deviations on $\log Y_t$ in (7).

(b) *Computation results*

Estimates computed on the basis of observations for the periods 1900–39 and 1946–55 give the following numerical values for the constants in the production function:

$$\text{est } A = \hat{A} = 2{\cdot}262; \text{ est } \alpha = \hat{\alpha} = 0{\cdot}203; \text{ est } \beta = \hat{\beta} = 0{\cdot}763; \text{ est } \gamma = \hat{\gamma} = 0{\cdot}0181$$

with dispersions for α, β, and γ of respectively

$$\hat{\delta}_\alpha = 0{\cdot}101 : \hat{\delta}_\beta = 0{\cdot}191 : \hat{\delta}_\gamma = 0{\cdot}0029.$$

If these estimates are used and the stochastic residual is disregarded the production function becomes

$$Y_t = 2{\cdot}262 \,.\, C_t^{0{\cdot}203} \,.\, L_t^{0{\cdot}763} \,.\, e^{0{\cdot}0181 \cdot t} \quad . \quad . \quad (8)$$

Formula (8) says: (i) A partial increase of the volume of real capital by 1 per cent will, *ceteris paribus*, raise the national product by 0·2 per cent. (ii) A partial increase of labour by 1 per cent will, *ceteris paribus*, raise the national product by 0·76 per cent. (iii) With constant capital volume and constant employment the national product will, as a result of gradually improving 'techniques', increase at the rate of approximately 1·8 per cent per annum.

The values for net national product for the years 1900–55 which can be derived from formula (8) and the available data on C and L on the whole fit in well with the actual observations. Table VI illustrates this, showing the magnitude of the percentage deviations (without regard to signs) between computed and actual values of the national product in the years under review.

As will be seen, the fit is particularly good for the post-war period, when the deviations apart from 1946 in no year exceed 2 per cent. For the inter-war period, when the production showed sharp short-run fluctuations, the deviations are notably larger.

TABLE VI

Comparison between Computed and Actual Figures for National Product

Numbers of observations (years) grouped according to the size of the percentage deviations between computed and estimated figures.

Period	Number of years in the period	Of which with percentage deviations				
		Less than 1%	1·0–2·9%	3·0–4·9%	5·0–6·9%	7% and more
1900–16	17	5	5	4	3	0
1916–39	23	5	8	3	2	5
1946–55	10	5	4	0	1	0
1900–55	50	15	17	7	6	5

As we already have seen, the estimates for the dispersion of the parameters in the production function are in some cases considerable. In particular, the dispersion is relatively large for the elasticity with respect to capital. If a rejection region of 0·05 is chosen we cannot reject the hypothesis $\alpha = 0$. The other parameters are, on the other hand, with this critical region significantly different from 0.

An impression of the reliability of the estimates may also be gained by studying their sensitivity to the choice of period. In the table below the results for the whole period 1900–55 are compared with estimates computed on the basis of data for some part-periods. (The figures in brackets give the estimated dispersions for some of the structural coefficients.)

Period	$\hat{A}$	$\hat{\alpha}$ $(\hat{\delta}_\alpha)$	$\hat{\beta}$ $(\hat{\delta}_\beta)$	$\hat{\gamma}$ $(\hat{\delta}_\gamma)$
1900–55 . . .	2·262	0·203 (0·101)	0·763 (0·191)	0·0181 (0·0029)
1917–55 . . .	6·085	0·282 (0·105)	0·513 (0·193)	0·0198 (0·0028)
1917–39 . . .	0·045	0·719 (0·795)	0·619 (0·288)	0·0118 (0·0169)
1922–39 . . .	0·057	0·622 (0·645)	0·390 (0·263)	0·0160 (0·0130)

Some of the parameters are found to depend strongly on which period the computations were made for. Another general feature is that the estimated dispersions are much bigger when the observations, for the post-war period are not included in the estimates.

We may add that insertion in (7) of the estimates for the periods 1917–39 and 1922–39 gives a very poor fit for the post-war years. The computed values for the net national product which these estimates give are far above the actual (largely because of the high values for $\hat{\alpha}$). On the other hand, the fit is affected only slightly if the estimates for 1900–55 are replaced with the estimates for the period 1917–55.

(c) *Conclusions*

The computations discussed in the foregoing can be judged from two rather different viewpoints. First, they may be regarded as experiments in macro-economic curve fitting. Second, the computations may be viewed as an attempt to determine the constants in a macro-economic structural relation.

From the first point of view the computations are an example of how it is possible to arrive at a comparatively simple macro-relation which gives a good fit for a relatively long period for an economy like the Norwegian. The actual development of three macro-economic variables (net national product, real capital volume, and employment volume) and time has been found to be such that a Cobb–Douglas function with a trend component gives a very good description of the actual course of events in the period 1900–55.

If the computations are interpreted as an attempt to determine the parameters in a production function, the results assume an entirely different meaning. For in that case the computation results are supposed to *explain* the growth of net national product in terms of capital input, labour input, and technique, considered as independent variables.

A necessary condition for this interpretation is that the shape we have chosen for the production function can be given an economic justification. In micro-analysis we are probably justified in regarding production functions of the Cobb–Douglas type as fairly well-founded hypotheses on the production laws. Whether one can expect to find stable production functions of equally simple shape in macro-analysis is an entirely different matter. Even more fundamentally, this is a question which concerns not only the shape of the function. It also raises the problem as to whether it is at all possible to explain production trends in macro-analysis merely by studying changes in macro-variables, without specifying, say, in which industries such changes occur. The basis for much of the macro-economic analysis, however, is presumably that it is possible to disregard such changes between factors in micro-analysis. On this basis it does not seem entirely unrealistic to reckon with a production function in macro-analysis of the type we have chosen.

There is little in our computation results to indicate that such a macro-type production function cannot be a useful hypothesis, rather the contrary. It is particularly interesting in this context that the production trend in the post-war period, which so obviously contradicts the idea of a constant marginal capital–output ratio, seems to have quite a natural explanation in the light of the production function estimated from the observations through the whole period 1900–55. Nevertheless, we would warn against placing too much confidence in the value of the parameters estimated, for several reasons. (i) Our choice of function shape is rather arbitrary. In this study the main reason for this choice is that a function shape of this type has to a great extent common usage in economic analyses. (ii) Particularly dubious is the assumption that technique, considered as a factor of production, can be represented by a trend component of such a simple time shape as the one we have used. (iii) The estimates on the value of the parameters are based on the assumption that the volume of employment and real capital can be regarded as two non-stochastic variables, and this is probably unrealistic. (iv) Substantial margins of error must be allowed for the observed variables, especially the employment data before 1930. Moreover, our capital data apply to capital in existence, while in the product function real capital in actual use is probably the relevant variable. (v) Finally, we may add to this list that the estimated dispersions for the constants are relatively large. This also applies to the estimates which were computed on the basis of the observations for the whole period 1900–55. However, having stated these qualifications, we shall in conclusion venture to discuss some implications which seem to follow from our estimates.

(d) *An economic interpretation of the computation results and their implications*

The most striking conclusion that can be drawn from our computation results is that the role of capital as a production-increasing factor appears to be considerably smaller than generally assumed. On the basis of (8) we can derive the following general formula for the relationship between the relative increase in national product, employment, capital, and technique (time):

$$\frac{dY_t}{Y_t} = \frac{0{\cdot}76}{(0{\cdot}191)}\frac{dL_t}{L_t} + \frac{0{\cdot}20}{(0{\cdot}101)}\frac{dC_t}{C_t} + \frac{0{\cdot}0181}{(0{\cdot}0029)}\,dt \qquad (9)$$

(Figures in brackets indicate estimated dispersions.) This means that: (i) An increase in labour by 1 per cent, with constant capital and with given technique, will raise the national product by 0·76 per cent. (ii) An increase in the capital by 1 per cent will, with constant labour and given technique, increase the national product by 0·20 per cent. (iii) The national product will have a tendency to grow at a rate of 1·81 per cent per annum even with unchanged labour and capital, simply as a result of gradual technical improvements.

If the formula holds, it permits us – for any period – to say something about the 'causes' of the percentage rise in the national product which has been achieved. For the period after 1948 employment has increased by an average of 0·6 per cent per annum and the real capital volume by 5·6 per cent per annum. According to the estimated production function, this warrants an annual rate of growth for the national product which may be computed thus:

Growth as a result of:

1. Rise in employment: 0·76 . 0·6	= 0·46 per cent per annum
2. Rise in capital: 0·20 . 5·6	= 1·12 ,, ,, ,, ,,
3. Improved technique etc.:	1·81 ,, ,, ,, ,,
Aggregate rate of growth	3·39 per cent per annum

The actual rate of growth in the period was virtually the same as indicated by the formula, viz. approx. 3·4 per cent per annum on average. Of this growth, only about one-third should therefore be attributable to the growth of capital.

This result should probably not be taken too literally, however. Even apart from the uncertainty connected with the constants in the product function (cf. the dispersion estimates), the interpretation of the trend component presents difficulties. In the foregoing we have assumed the trend component to represent 'technique' (in the widest sense) as special factor of production on line with labour and capital. It is certainly unrealistic, however, to assume that the rate of the technological progress is completely independent of the rate of increase in the capital volume. To put it differently, it is almost certain that the increase in the national product of 1·81 per cent per annum which has been ascribed to technique in the foregoing, would *not* have occurred without a simultaneous increase of the capital.

Even allowing for considerable margins of uncertainty for the parameters derived, they give a convincing explanation of the high and rising values which we found in Section IV for the marginal capital–output ratio for the years around 1948. If we transform the expression of the relative increments in formula (9), we get the following expression of the marginal capital–output ratio

$$\frac{dC_t}{dY_t} = \frac{1}{\frac{Y_t}{dC_t}\left(0{\cdot}76\,\frac{dL_t}{Lt} + 0{\cdot}0181\,dt\right) + 0{\cdot}20\frac{Y_t}{C_t}} \tag{10}$$

The formula states that the marginal capital–output ratio varies inversely with the rate of growth in labour (dL_t/L_t), and rises with the fraction of national product devoted to investment, e.g. the net investment ratio (dC_t/Y_t) and the size of the average capital–output ratio (C_t/Y_t). For the years after 1948 the net investment ratio has averaged approximately 17 per cent, the increase in labour approximately 0·6 per cent per annum, and the average capital–output ratio approximately 3·2. This should, according to (10) give a marginal capital–output ratio of 5·12. The actual figure was, as previously mentioned, 5·13. (The close agreement between the computed and the actual figure is, of course, only a reflection of the fact that our production function fits so well with the data for the period in question.) With a net investment ratio of the order of magnitude we had in the inter-war period, about 10 per cent, and equal conditions otherwise, the value of the marginal capital–output ratio would have been approximately 3·45 according to the formula. This puts an entirely new light on the trend in recent years. The high marginal capital–output ratio after 1948 is in no way 'contradictory to the experience of earlier times', on the contrary, it seems to have a natural explanation in our high investment level.

If the effects of a capital increase on the national product are as slight as our estimates suggest, it means that the chances of speeding up the growth in the national product by expanding the scope of investments are smaller than hitherto assumed. A transformation of the formula above gives us the following expression of the net investment ratio (dC_t/Y_t) which is required to achieve a given rate of growth for the national product (dY_t/Y_t) when the increase in labour (dL_t/L_t) is given and when the average capital–output ratio (C_t/Y_t) is also given.

$$\frac{dC_t}{Y_t} = \frac{1}{0{\cdot}20} \cdot \frac{C_t}{Y_t}\left(\frac{dY_t}{Y_t} - 0{\cdot}76\,\frac{dL_t}{L_t} - 0{\cdot}0181dt\right) \qquad (11)$$

In the following table we have compiled rounded rates of growth for the national product derived from alternative assumptions for the net investment ratio and changes in employment. The table is based on an average capital–output ratio corresponding to the ratio in Norwegian economy today, namely approximately 3·40.

Net Investment Ratio (dC_t/Y_t)	Employment Increase Per cent per annum (dL_t/L_t)			
	0	0·5	1·0	1·5
	Rates of Growth for National Product Per cent per annum			
0	1·8	2·2	2·6	3·0
10	2·4	2·8	3·2	3·5
15	2·7	3·1	3·5	3·8
20	3·0	3·4	3·7	4·1
30	3·6	4·0	4·3	4·7

It is clear that the rate of growth of the national product is affected comparatively little by the level of investment. Without any increase in employment it is necessary to have as high investment ratio as 20 per cent in the next years to accomplish a 3 per cent growth per annum in the national product. If we reckon with an employment increase of, for example, 0·5 per cent per annum, a net investment ratio of 15 per cent (somewhat lower than the average in Norway in the last years) will give a growth in the national product of approximately 3·1 per cent per annum. To raise the rate of growth to 4 per cent would – if our computations are realistic – require a net investment ratio of no less than 30 per cent.

In light of the above, it appears that the rate of growth which can be attained in a society like the Norwegian depends to a much smaller extent than was hitherto believed on the investment policy followed. Whether the rate of investment within reasonable limits is high or low, the national product with constant employment will rise by 2–3 per cent per annum, largely because the technical factor alone automatically warrants a growth which here has been estimated at roughly 1·8 per cent per annum. The pace can be increased somewhat beyond this by maintaining a high investment level, but not very much.

If this is correct, it has obvious economic-policy implications. A stringent economic policy designed to maintain a high investment level becomes much harder to justify. One question which naturally arises in this connection is whether the trend factor here termed 'technique' in itself is an invariable or whether it can be influenced, for example by placing more emphasis on the education of efficient management, technicians, and workers. This is an interesting and important question. If the answer is positive, the low effect of investment suggested above gives a hint that a higher rate of growth could possibly be obtained, by releasing resources now devoted to investment for a greater effort in education and research, for example. However, to this the present study can provide no answer.

APPENDIX OF TABLES

TABLE I

Fixed Real Capital[1] *by Type at the End of the Years 1899–1939 and 1945–1955*

At constant (1938) prices. Millions of kroner

End of Year	Total Fixed Real Capital	Of which: Government Building and Construction	Building and Construction of Enterprises	Machinery, Tools, and Transport Equipment Excl. Ships	Ships and Boats
1899	7,250	1,052	5,351	472	375
1900	7,417	1,073	5,451	505	388
1901	7,583	1,093	5,551	532	407
1902	7,724	1,114	5,631	557	422
1903	7,840	1,131	5,695	578	436
1904	7,970	1,145	5,770	600	455
1905	8,075	1,156	5,835	622	462
1906	8,212	1,165	5,913	649	485
1907	8,395	1,174	6,024	689	508
1908	8,581	1,183	6,147	731	520
1909	8,746	1,195	6,260	770	521
1910	8,961	1,207	6,405	813	536
1911	9,239	1,224	6,580	860	575
1912	9,567	1,248	6,782	924	613
1913	9,905	1,278	6,994	991	642
1914	10,224	1,311	7,217	1,044	652
1915	10,550	1,336	7,460	1,077	677
1916	10,904	1,354	7,756	1,116	678
1917	11,098	1,370	8,026	1,145	557
1918	11,340	1,393	8,253	1,164	530
1919	11,745	1,424	8,507	1,228	586
1920	12,203	1,454	8,782	1,287	680
1921	12,403	1,506	8,909	1,278	710
1922	12,573	1,590	9,002	1,280	701
1923	12,804	1,671	9,136	1,300	697
1924	13,070	1,727	9,315	1,320	708
1925	13,351	1,769	9,470	1,341	771
1926	13,536	1,813	9,560	1,339	824
1927	13,736	1,856	9,674	1,354	852
1928	14,082	1,896	9,852	1,412	922
1929	14,500	1,939	10,037	1,500	1,024
1930	14,990	1,982	10,227	1,569	1,212
1931	15,317	2,030	10,368	1,599	1,320
1932	15,482	2,076	10,536	1,628	1,242
1933	15,662	2,116	10,702	1,651	1,193
1934	15,926	2,160	10,911	1,694	1,161
1935	16,319	2,214	11,165	1,773	1,167
1936	16,851	2,280	11,481	1,899	1,191
1937	17,564	2,365	11,814	2,058	1,327
1938	18,192	2,422	12,141	2,204	1,425
1939	18,874	2,492	12,528	2,360	1,494
1945	16,461	2,545	11,423	1,673	820
1946	17,157	2,614	11,781	1,788	974
1947	18,256	2,698	12,289	2,004	1,265
1948	19,311	2,796	12,802	2,240	1,473
1949	20,413	2,913	13,374	2,465	1,661
1950	21,587	3,040	14,006	2,744	1,797
1951	22,760	3,159	14,631	3,070	1,900
1952	24,051	3,287	15,327	3,483	1,954
1953	25,435	3,444	16,055	3,879	2,057
1954	26,868	3,636	16,776	4,337	2,119
1955	28,284	3,839	17,477	4,719	2,249

[1] Structures and equipment only.

TABLE II

Fixed Real Capital[1] by Industry and by Types of Assets at the End of the Years 1899, 1939, and 1953

At constant (1938) prices. Millions of kroner

Industry, Type of Asset	1899	1939	1953
Agriculture and forestry	1,112	2,090	2,382
Building and construction	1,014	1,880	2,043
Machinery	92	188	301
Transport equipment	6	22	38
Fishing	108	282	280
Fishermen's sheds, piers, etc.	23	49	42
Boats	60	185	185
Equipment	25	48	53
Whaling (boats)	5	70	105
Mining and manufacturing	555	2,552	4,067
Building and construction	332	1,277	1,902
Machinery, etc.	215	1,236	2,100
Transport equipment	8	39	65
Electricity and gas	30	1,100	2,083
Building and construction	21	900	1,718
Machinery, etc.	9	200	365
Business buildings (buildings)	454	930	1,250
Dwellings (buildings)	3,062	6,200	7,289
Shipping (ships)	310	1,239	1,767
Railway transport	378	964	1,343
Railroad construction	355	843	1,223
Rolling stock	23	121	120
Tramways, etc.	17	98	95
Tramway, etc., construction	14	79	75
Rolling stock	3	19	20
Road transport (transport equipment)	5	133	232
Air transport (aircraft)	—	3	20
Communication (building and communication installations)	46	220	348
Wholesale and retail trade	50	198	336
Transport equipment	8	50	86
Other equipment	42	148	250
Harbour construction	30	150	165
General government building and construction	1,052	2,492	3,444
Highways and bridges	540	1,320	1,771
Other building and construction	512	1,172	1,673
Other industries	36	153	229
Transport equipment	—	3	9
Other equipment	36	150	220
Total fixed real capital	7,250	18,874	25,435
Of which:			
Building and construction of enterprises	5,351	12,528	16,055
Government building and construction	1,052	2,492	3,444
Ships and boats	375	1,494	2,057
Transport equipment excl. ships	53	390	590
Machinery and other equipment	419	1,970	3,289

[1] Structures and equipment only.

TABLE III

Total Fixed Real Capital[1] *and Net Domestic Product at Constant (1938) Prices, and Total Employment in Thousands of Man-years 1900–39 and 1946–55*

Year	Total Fixed Real Capital	Net Domestic Product	Total Employment	Average Capital–Output Ratio	Real Capital per Man-year
	Millions of kroner	Millions of kroner	Thousands of Man-years		Kroner
	1	2	3	4 = 1 ÷ 2	5 = 1 ÷ 3
1900	7,417	1,821	977	4·07	7,592
1901	7,583	1,860	987	4·08	7,683
1902	7,724	1,882	993	4·10	7,778
1903	7,840	1,858	996	4·22	7,871
1904	7,970	1,850	999	4·31	7,978
1905	8,075	1,860	1,002	4·34	8,059
1906	8,212	1,931	1,005	4·25	8,171
1907	8,395	2,019	1,008	4·16	8,328
1908	8,581	2,085	1,013	4·12	8,471
1909	8,746	2,119	1,023	4·13	8,549
1910	8,961	2,213	1,027	4·05	8,725
1911	9,239	2,302	1,041	4·01	8,875
1912	9,567	2,406	1,055	3·98	9,068
1913	9,905	2,528	1,071	3·92	9,248
1914	10,224	2,589	1,090	3·95	9,380
1915	10,550	2,726	1,107	3·87	9,530
1916	10,904	2,870	1,124	3·80	9,701
1917	11,098	2,605	1,142	4·26	9,718
1918	11,340	2,455	1,161	4·62	9,767
1919	11,745	3,084	1,178	3·81	9,970
1920	12,203	3,171	1,202	3·85	10,152
1921	12,403	2,734	1,107	4·54	11,054
1922	12,573	3,037	1,122	4·14	11,206
1923	12,804	3,127	1,179	4·10	10,860
1924	13,070	3,099	1,201	4·22	10,883
1925	13,351	3,245	1,173	4·11	11,382
1926	13,536	3,241	1,097	4·18	12,339
1927	13,736	3,380	1,096	4·06	12,533
1928	14,082	3,573	1,151	3·94	12,235
1929	14,500	3,888	1,188	3·73	12,205
1930	14,990	4,196	1,187	3·57	12,628
1931	15,317	3,791	1,153	4·04	13,284
1932	15,482	3,999	1,178	3·87	13,143
1933	15,662	4,093	1,192	3·83	13,139
1934	15,926	4,253	1,213	3·74	13,129
1935	16,319	4,480	1,240	3·64	13,160
1936	16,851	4,808	1,276	3·51	13,206
1937	17,564	5,012	1,309	3·50	13,418
1938	18,192	5,102	1,330	3·57	13,678
1939	18,874	5,353	1,358	3·53	13,898
1946	17,157	5,555	1,394	3·09	12,308
1947	18,256	6,311	1,441	2·89	12,669
1948	19,311	6,567	1,467	2·94	13,164
1949	20,413	6,772	1,489	3·01	13,709
1950	21,587	7,073	1,499	3·05	14,401
1951	22,760	7,322	1,509	3·11	15,083
1952	24,051	7,629	1,522	3·15	15,802
1953	25,435	7,812	1,522	3·26	16,712
1954	26,868	7,915	1,537	3·39	17,481
1955	28,284	8,323	1,534	3·40	18,438

[1] Structures and equipment only.

TABLE IV

Fixed Real Capital[1] by Type for Selected Years

Current prices. Millions of kroner

End of Year	Total Fixed Real Capital	Of which			
		Government Building and Construction	Building and Construction of Enterprises	Machinery, Tools, and Transport Equipment Excl. Ships and Boats	Ships and Boats
1900	3,456	456	2,382	332	286
1905	3,559	484	2,398	352	325
1910	4,291	552	2,914	463	362
1915	6,855	770	4,566	778	741
1920	25,629	2,771	17,248	3,051	2,559
1925	17,108	2,142	11,932	1,962	1,072
1930	12,209	1,548	8,243	1,337	1,081
1935	12,800	1,656	8,675	1,509	960
1939	19,588	2,656	12,804	2,464	1,664
1946	32,802	5,113	21,830	3,506	2,353
1950	51,154	7,053	30,939	6,495	6,667
1955	90,763	12,753	52,169	13,874	11,967

[1] Structures and equipment only.

TABLE V

National Wealth of Norway at the End of the Year 1953

Millions of kroner at current prices

		Total [1]	Of which [1] Public [7]
A. *Enterprises*	total	89,700	9,767
I. Reproducible assets	total	86,655	9,767
1. Structures	total	45,977	8,203
(a) Dwellings [2]		22,013	..
(b) Agricultural		5,413	..
(c) Other		18,551	8,203
2. Equipment	total	21,078	1,564
(a) Agricultural		831	..
(b) Other		20,247	1,564
3. Inventories [3]	total	19,600	..
(a) Livestock		1,300	..
(b) Other agricultural		800	..
(c) Other		7,500	..
(d) Standing timber		10,000	..
II. Non-reproducible assets, land	total	3,045	..
(a) Agricultural		3,045	..
(b) Forest		..	..
(c) Other		..	..
B. *Government* [4]	total	10,642	
I. Reproducible assets	total	10,642	
1. Structures [5]		10,642	
2. Equipment		..	
3. Inventories		..	
II. Non-reproducible assets, land	total	..	
C. *Consumer durables*	total	550	
1. Passenger cars and other vehicles [6]		550	
2. Other		..	
D. *Foreign assets*	total	−1,370	
1. Monetary metals		185	
2. Other net foreign assets		−1,555	
Total		99,522	

[1] .. Not available; not included in totals.
[2] All dwellings.
[3] Livestock and standing timber included.
[4] Only general government (military assets not included). For the distinction between general government and government enterprises and public corporations (which are entered under A. Enterprises, column public) see – *A System of National Accounts and Supporting Tables*, United Nations, pp. 11, 12.
[5] Roads, bridges, and public schools included.
[6] Only privately owned cars, wholly or partly in use for private consumption.
[7] Only government enterprises and public corporations, for a further explanation see [4].