# Alfred Kähler’s

## *Die Theorie der Arbeiterfreisetzung durch die Maschine*

An early contribution to the analysis of the impact of automation on workers

*by*

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# Alfred Kähler's *Die Theorie der Arbeiterfreisetzung durch die Maschine*

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## 1. Introduction

This essay provides an assessment of Alfred Kähler's study *Die Theorie der Arbeiterfreisetzung durch die Maschine* (The theory of labour displacement by machinery), which was submitted as a doctoral dissertation at the University of Kiel in 1932 and published (in German) in 1933. Kähler's study was conducted in the late 1920s and early 1930s under Adolph Lowe's guidance at the *Institute of World Economics* in Kiel.[1] It contains the first attempt to provide a systematic analysis of the problem of labour displacement and compensation by machinery within the framework of a multisectoral model of the economy. As will be shown below, the so-called "total circulation schemes" ("Gesamtumschlagsschemata") developed by Kähler can be interpreted as an early formulation of a closed (static) input output model.[2] Moreover, Kähler also provided a discussion of the associated price model and of the choice of technique problem.[3]

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1 Alfred Kähler (1900–1981) studied economics and law at the Universities of Kiel and Berlin from 1924 to 1927. He then obtained the post of a director of an adult education centre in Harriesleefeld (near the Danish border), which he held from 1928 to 1933. During this period he also participated actively in Lowe's seminars at the *Kiel Institute of World Economics* and conducted research on his doctoral dissertation, which he submitted in 1932 at the University of Kiel. He emigrated from Nazi Germany in 1934 and found refuge at the *New School for Social Research* in New York. For an overview of Kähler's academic career and more biographical details see Hagemann (1998).

2 It is somewhat surprising that Kähler makes no reference to Wassily Leontief's doctoral dissertation *Die Wirtschaft als Kreislauf* (1928), particularly since the latter was also a member of the scientific community around Adolph Lowe at the *Institute of World Economics* (from 1927 to 1928 and from 1930 to 1931). Other members of Lowe's research group were, amongst others, Gerhard Colm, Fritz Burchardt, Hans Neisser, and Jakob Marschak.

3 The originality of Kähler's study was first recognized by Mettelsiefen (1981, 1983), who provided a comprehensive assessment of Kähler's contribution to the German "rationalization debate". The present essay draws partly on Mettelsiefen's work.

The structure of the paper is the following. The next section contains a brief summary of the first, “critical” part of Kähler’s study that is devoted to a critical reconstruction of the analyses of the machinery problem in the writings of the classical economists and to the development of a model of the economic circular flow. The findings of this reconstruction provide the basis of Kähler’s own, “positive” contribution in the second part of his treatise, which will be discussed in Section 3. In Section 4 Kähler’s approach is briefly compared with the model developed by Leontief and Duchin (1986). Section 5 summarizes the argument.

## 2. Kähler’s reconstruction of the classical theory of labour displacement and compensation and his elaboration of a “total circulation scheme”

Kähler begins his study with a critical discussion of earlier contributions to the analysis of the problem of labour displacement and compensation by machinery. He provides an excellent overview of the major contributions to the long controversy over the impact of machinery on employment. He rightly emphasizes that this controversy really centers around the question of the precise conditions for the compensation of technological unemployment. For neither is the possibility of the eventual reemployment the originally displaced workers denied by the so-called displacement theorists, nor is it claimed by the advocates of the compensation theory that there is no technological unemployment in the short run. The disputed question is rather how fast and under what conditions compensation takes place. As Kähler points out, in the contributions of the classical political economists, and in particular in those by Ricardo and Marx, a sufficient accumulation of capital is seen as the major precondition for a successful compensation.

While economists like Malthus and Sismondi had concentrated attention on the possibility of a lack in total purchasing power, and thus in total effective demand, in consequence of the introduction of machinery, Ricardo had denied the possibility of a “general glut”, and had instead introduced the capital stock dimension of the compensation problem. Kähler makes it clear that his own contribution is meant to elaborate on Ricardo’s approach, and that he will take over two important elements from the latter’s analysis. First, he shares Ricardo’s opinion that the problem of technological unemployment is not primarily a problem of an insufficient effective demand (and thus should not be mixed up with that problem), but rather a problem of an insufficient stock of productive capital. Second, he also embraces Ricardo’s view that the dominant form of technical progress that may cause large scale labour displacement consists in the conversion of circulating into fixed capital. He criticizes Ricardo, however, for having based his analysis on wage-fund reasoning, and argues that the main obstacle for the reemployment of the displaced workers is not an insufficient wage fund but rather an insufficient stock of complementary fixed capital.

Kähler thus agrees with a criticism of Ricardo's argument that was already raised by Marx. Yet in Kähler's view Marx in his own writings had nowhere provided a thorough analysis of the displacement and compensation problem himself, although the idea of a "rising organic composition of capital" and the concept of the "industrial reserve army" occupied a prominent place in his theoretical system (*ibid*.: 47). Kähler's main criticism of Marx's displacement theory is closely related to his own idea (which he had taken over from Ricardo) that the displacement of labour is mainly connected with a "lengthening of the turnover period of capital". Since in Marx's schemes of reproduction only those parts of the productive capital are shown which are used up during the process of production and have to be replaced periodically, this phenomenon cannot properly be taken into account. Kähler claims that a proper analysis of this phenomenon requires the elaboration of a total circulation scheme that also incorporates the *stocks of productive capital*.

It was thus Kähler's explicit purpose to take up, and elaborate on, the classical approach to the machinery problem in the tradition of Ricardo and Marx, which 'depicts the capitalistic process as a race between displacement of labor through technological progress and reabsorption of labor through accumulation' (Neisser 1942: 70).

## Kähler's total circulation scheme

Before we enter into a discussion of Kähler's "positive analysis" of the impact of machinery on workers, it seems appropriate to note some salient features of the total circulation schemes on which this analysis is based. In elaborating these schemes, Kähler made extensive use of a study by Fritz Burchardt (1931-32), which contained a critical assessment of the models of the circular flow developed by Böhm-Bawerk and Marx. In this essay Burchardt had sought to provide a synthesis of the Austrian stages model and the sectoral model of production which originated from Quesnay and Marx.

Following Burchardt, Kähler criticized Böhm-Bawerk's production model for its neglect of the circular relations of production. In particular, he charged Böhm-Bawerk for having neglected a characteristic feature of modern industrial systems, namely the physical self-reproduction of certain fixed capital goods (i.e. the "production of machines by means of machines") by assuming that at the first stage of the uni-directional Austrian production process only original inputs like labour and land are required. But Kähler also saw the need for an important modification in Marx's schemes of reproduction, which otherwise he considered to be the most elaborate version of a model of the economic circular flow. Like Burchardt, and later Lowe (1976), he criticized Marx for having failed to integrate the *sectoral stocks of productive capital* into his schemes.

In setting up his own scheme, Kähler starts from a description of the "cost composition" of the different commodities, that is, he starts from the assumption of *given technological coefficients*.[4] He notes immediately that 'the technique can of course not be chosen at random; it will primarily be determined by considerations of rentability' (*ibid*.: 84). But at this stage of the analysis the problem of the choice of technique is set aside. The methods of production in use are taken to be known, and to consist of a set of linear-limitational single production processes with constant returns to scale — or, as Kähler put it:

> 'The relative cost composition in the production of coal is the same *as long as the technique remains the same*. A change in the total volume of coal production would have *no influence* on this cost composition' (*ibid.*: 84; emphases added).

Apart from the "cost composition" of the different productions Kähler also takes as given the "composition of consumption", that is, the proportions in which the commodities are demanded are also taken to be known (*given requirements for use*). As will be seen below, Kähler indeed conceived of the consumption activities of the workers as "the production of labour power by means of commodities and labour power", so that analytically there is no difference between production and consumption activities. In the scheme developed by Kähler all commodities are assumed to be produced by using some produced means of production as inputs. The production (and consumption) of commodities is thus seen as a circular process:

> 'Let us begin, then, with the elaboration of our model of the circular flow, which has to show the production as well as the use of the different goods. The main users are of course the final consumers. But it would be wrong to suppose that they alone determine the size of the productions. The total volume of coal production, for instance, depends on the use of coal in the machinery industry as much as on the use of the final consumers. ... But the use of coal in the machinery industry depends, inter alia, on the total volume of machinery production, which itself is codetermined by the amount of machines that are used in the mining industry. *The determination of the size of one sector thus always presupposes the knowledge of the size of the other productions* — which, however, can only be specified once the size of the first sector has been determined' (*ibid*.: 83-4).

Finally, Kähler pointed out that the above assumptions suffice to determine all the quantity relations (except for a scale factor):

> 'The *absolute* numbers can only be determined if at least for one of the productions an absolute number is specified. The *relative* size of the productions, however, can be determined without difficulty from *a general system of equations*. The resulting proportions are those that will have to hold in the economy under consideration, even if it grows. These proportions indeed change only if there are shifts in human

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4 As will be seen below, Kähler's price system is chosen in such a way that the "cost composition" coincides with the physical input composition of the different commodities.

consumption or if, because of technical changes, the use of the means of production changes' (*ibid*.: 87; emphases added).

**3. The analysis of labour displacement and compensation**

Kähler starts his investigation by developing a comprehensive classification of different forms of technical progress that distinguishes between 27 types of technical progress, three of which are then analysed in detail. The following discussion will be confined to a summary of Kähler's analysis of the third and, in his view, practically most relevant type of technical progress: the introduction of a new, direct labour-saving method that is associated with a "lengthening of the turnover period of capital".[5] For this case Kähler attempts to provide a systematic analysis of the labour displacement and compensation process by means of four different input output tables, which are meant to depict the economic system in four successive "phases" of the transition from an "old" to a "new" technique:

(*i*) Kähler's first table (*scheme* I) describes the circular flow relations of the economic system in the initial situation, before the introduction of technical progress, at $t_0$. The system is supposed to be in a stationary equilibrium with zero profits; there is no (net) saving and no investment.

(*ii*) The next table (scheme II) is meant to capture the phase of the labour displacement. It depicts the (hypothetical) situation of the economic system at $t_1$, when some of the workers have been displaced because a new, labour-saving method was introduced in a particular industry. The occurrence of technological unemployment is accompanied by the emergence of technological extra profits that provide a possible source for capital accumulation.

(*iii*) In the next step Kähler turns to the compensation phase, in which a successive re-employment of the originally displaced workers occurs because the technological extra profits are saved and invested. *Scheme* III shows the state of the economic system at the end of this phase, that is at $t_2$, when the original labour force is again fully employed.

(*iv*) In the final step of the analysis Kähler then investigates the consequences of a redistribution of the productivity gains that are associated with the new technique. This redistribution of the productivity gains from the recipients of extra profits to the recipients of wages is associated with a new system of relative prices and an adjustment in the structure of production to the new structure of final demand. The corresponding *stationary flow equilibrium* of the economic system at $t_3$ is depicted in Kähler's scheme IV.

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5 For a summary of Kähler's analysis of other types of technical progress see Mettelsiefen (1981: 139-51) and (1983).

(***i***) ***Initial situation***. In order to describe the economic system in the initial situation before the introduction of the new machinery Kähler develops a so-called “Gesamtumschlagsschema” (“total circulation scheme”). This table (see *scheme* I below) shows not only the (annual) interindustry flows but, in addition, also the associated sectoral capital stocks. The numerical values in Kähler’s table are meant to depict both the quantity and the value magnitudes, since the system is normalized in such a way that all prices are equal to one. Labour (or rather the commodity “labour power”) is treated like a produced means of production: similar to all the other commodities the table shows the annual flows and stocks of the commodity inputs that are required to reproduce the commodity “labour power”.

***Scheme* I**
(Initial scheme)

| **Inputs** | **Flows and Stocks in the production of** | | | | | | | | | | ***Total Flow*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coal & Iron* | | *Machines* | | *Buildings* | | *Agriculture* | | *Labour* | | |
| | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | |
| *Coal & Iron* | 90,8 | 6 | 156,4 | 26 | 41,5 | 30 | 65,2 | 16 | 100 | 30 | 454 |
| *Machines* | 45,4 | 225 | 39,1 | 195 | 41,5 | 203 | 65,2 | 240 | 200 | 200 | 391 |
| *Buildings* | 45,4 | 360 | 39,1 | 390 | 0 | 0 | 130,4 | 800 | 200 | 2000 | 415 |
| *Agriculture* | 45,4 | 5 | 0 | 0 | 41,5 | 30 | 65,2 | 70 | 500 | 10 | 652 |
| *Labour* | 227 | 25 | 156,4 | 30 | 290,5 | 210 | 326 | 250 | | | 1000 |
| ***Total Production*** | 454 | 621 | 391 | 641 | 415 | 475 | 652 | 1376 | 1000 | 2240 | |
| Total stock of productive capital = 3113, Total wages = 1000, Productive capital : Total wages = 3,11. | | | | | | | | | | | |

In another table (from which *scheme* I is derived) Kähler shows the “cost composition of production”. In this table the shares of the different inputs in total costs are calculated by setting the “sum of the cost components” equal to 10:

***Scheme* Ia**

| **Inputs** | **Composition of the costs in the production of** | | | | | |
|---|---|---|---|---|---|---|
| | *Coal & Iron* | *Machines* | | *Buildings* | *Agriculture* | *Labour* (Profits) |
| | | Old | New | | | |
| *Coal & Iron* | 2 | 4 | 6 | 1 | 1 | 1 |
| *Machines* | 1 | 1 | 2 | 1 | 1 | 2 |
| *Construction* | 1 | 1 | 1 | 0 | 2 | 2 |
| *Agricultural goods* | 1 | 0 | 0 | 1 | 1 | 5 |
| *Labour* | 5 | 4 | 2 | 7 | 5 | |
| (Profits) | | | 1 | | | |
| **Sum of the cost components** | 10 | 10 | 12 | 10 | 10 | 10 |

It is easily recognized that Kähler's total circulation scheme can be interpreted as a closed, static Leontief system. From table I (and Ia) we can calculate the following matrix of the production (and consumption) coefficients:

$$\mathbf{A} = \begin{pmatrix} 0.2 & 0.4 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.1 & 0.1 & 0.2 \\ 0.1 & 0.1 & 0 & 0.2 & 0.2 \\ 0.1 & 0 & 0.1 & 0.1 & 0.5 \\ 0.5 & 0.4 & 0.7 & 0.5 & 0 \end{pmatrix},$$

which consists of the usual matrix of interindustry production coefficients, $\tilde{\mathbf{A}}$, of the column vector **c,** and of the row vector $\mathbf{l}^T$, that is, $\mathbf{A} = \begin{pmatrix} \tilde{\mathbf{A}} & \mathbf{c} \\ \mathbf{l}^T & 0 \end{pmatrix}$. It is also easily recognized that Kähler's table fulfills the conditions $(\mathbf{A}_\mathrm{I} - \mathbf{I})\mathbf{x}_\mathrm{I} = 0$ and $\tilde{\mathbf{p}}_\mathrm{I}^T(\mathbf{A}_\mathrm{I} - \mathbf{I}) = 0$, with $\tilde{\mathbf{p}}_\mathrm{I}^T = (\mathbf{p}_\mathrm{I} \quad w)^T$. Kähler adopts the normalization $\mathbf{l}_\mathrm{I}^T\mathbf{x}_\mathrm{I} = 1000$ and $w = \mathbf{p}_\mathrm{I}^T\mathbf{c} = 1$, so that prices and quantities are determined as $\tilde{\mathbf{p}}_\mathrm{I}^T = (1,1,1,1,1)$ and $\mathbf{x}_\mathrm{I}^T$ = (454, 391, 415, 652, 1000).

It should be pointed out that Kähler's table contains not only the annual flows but also the necessary sectoral *stocks* of the means of production (and of the means of consumption) for each sector.[6] According to Kähler, it will be necessary in all of the sectors to hold some inventory stocks of raw materials and semi-finished products ('working capital') and some stocks of permanent means of production ('fixed capital'). Although Kähler notes a difference, he nevertheless lumps together these inventory and fixed capital stocks:

> 'If the machine industry, for instance, uses 10,9 units of coal per annum, it will of course not be necessary for this industry to hold a "stock of coal capital" of the same amount, for at each moment it clearly needs to have only some fraction of the total annual use of coal in the inventory. But a certain stock of coal, part of which is continuously used up and replenished, will nevertheless have to be held in this industry. The average stock of coal will then constitute the necessary capital stock which underlies the use processes. The same applies also with regard to the relation between the use of machine tools and the stock of machine tools. In order to continuously use up 16,4 units of machines per annum, one will again need to hold a certain stock of machines which in this case however will have to be larger than the amount that is annually used up' (*ibid*.: 93).

If we denote the matrix of the sectoral stocks of fixed and working capital per unit of output with **K**, and the corresponding matrix of the depreciation coefficients with **D**,[7] then the total

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6 Fritz Burchardt (1931-32) had already pointed out the necessity of introducing the sectoral capital *stocks* into the Marxian schemes of reproduction.

7 In the case of typical "working capital" inputs, like "coal & iron", the numerical relation of the sectoral stocks to the corresponding flows chosen by Kähler seems arbitrary. With

stocks of the different means of production (and of the means of consumption) in Kähler's table I are given by $\mathbf{k} = \mathbf{K}_I \mathbf{x}_I = \mathbf{D}_I^{-1} \mathbf{A}_I \mathbf{x}_I$, where

$$\mathbf{K}_I = \begin{pmatrix} 0{,}013 & 0{,}066 & 0{,}072 & 0{,}024 & 0{,}03 \\ 0{,}5 & 0{,}5 & 0{,}5 & 0{,}368 & 0{,}2 \\ 0{,}8 & 1 & 0 & 1{,}23 & 2 \\ 0{,}01 & 0 & 0{,}07 & 0{,}1 & 0{,}01 \\ 0{,}06 & 0{,}08 & 0{,}5 & 0{,}38 & 0 \end{pmatrix} \text{ and } \mathbf{D}_I = \begin{pmatrix} 15 & 6 & 1{,}38 & 4 & 3{,}3 \\ 0{,}2 & 0{,}2 & 0{,}2 & 0{,}27 & 1 \\ 0{,}13 & 0{,}1 & 0 & 0{,}16 & 0{,}1 \\ 9 & 0 & 1{,}38 & 0{,}93 & 50 \\ 9 & 5{,}2 & 1{,}38 & 1{,}3 & 0 \end{pmatrix}.$$

**(*ii*) *Phase of labour displacement.*** Starting from *scheme* I, Kähler next seeks to ascertain the amount of labour displacement that is associated with the introduction of a new method of production in a particular industry. He assumes that the introduction of technical progress takes place in the machine producing industry. The new method of machinery production is depicted as a change in the "cost composition" of that industry:

> 'While in our initial scheme ... we assumed that four value units of labour were combined with one value unit of buildings, one value unit of machinery and four value units of coal & iron in the production of machines, we now assume that two units of labour are combined with one unit of buildings, two units of machinery and six value units of coal & iron. ... Since we calculate the units at the old cost prices, this change in the value composition is identical with a change in the composition of the use values' (*ibid*.: 112-3).

The columns 2 and 3 of *scheme* Ia thus show the change in the *physical* input requirements per unit of output. In interpreting the third column of this table it must be noticed that Kähler chose to describe the new production method by altering the "total sum of the cost components" in the machinery industry from 10 to 12, in order to take account of the productivity increase that is associated with the new method of production:

> 'After the introduction of technical progress in the production of machines it must be possible, since the quantity units and the value units had before been set equal to one another, that a given amount of value units can produce a larger amount of quantity units. The amounts of the input flows are to be reckoned at their old values, at which they must also be purchased. We assume in our example that the output (in quantity terms) exceeds the former amount by 1/11. Formerly, an input of 11 units in value terms resulted in a production of 11 units in quantity terms; now, with the new technique, it is possible to produce with the same total costs 12 of the former units. In order to simplify the further analysis we shall assume that in spite of the cost reduction the value of the machines remains unchanged, so that 1/12 of the product's value emerges as profit' (*ibid*.: 113).

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regard to the stocks of typical "fixed capital" inputs like "machines" and "buildings", however, Kähler supposes more or less identical depreciation rates in all sectors.

Since the "costs" are still calculated at the former prices, the new "cost composition" of machine production gives immediately the new production coefficients: The amounts of input per unit of output in the machinery industry thus amount to 6/12 units of coal & iron, 2/12 units of machinery, 1/12 units of buildings, and 2/12 units of labour. Finally, a further "cost element", amounting to 1/12 of the "construction costs" of a machine, is made up of (extra) profits.[8] A corresponding change of the second column gives the "new" matrix of the production and consumption coefficients

$$\mathbf{A}_{\mathrm{II}} = \begin{pmatrix} 0.2 & 0.5 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.17 & 0.1 & 0.1 & 0.2 \\ 0.1 & 0.08 & 0 & 0.2 & 0.2 \\ 0.1 & 0 & 0.1 & 0.1 & 0.5 \\ 0.5 & 0.25 & 0.7 & 0.5 & 0 \end{pmatrix},$$

in which the element $a_{52}$ depicts the "input of labour *plus technological extra-profit* per unit of output" in the machinery industry.[9] With the normalization $\mathbf{l}_{\mathrm{II}}^{T}\mathbf{x}_{\mathrm{III}} = 1000$ (where $\mathbf{l}_{\mathrm{II}}^{T}$ is the fifth row of the matrix $\mathbf{A}_{\mathrm{II}}$), and taking into account that $\mathbf{x}_{\mathrm{III}}^{T}(\mathbf{A}_{\mathrm{II}} - \mathbf{I}) = 0$, this allows to determine the new numerical values of the flow magnitudes depicted in Kähler's *scheme* III (see below).

Starting from this new input output table, Kähler then calculates the (hypothetical) labour displacement that is associated with the new technique. This calculation is based on the assumption that the new production method that has been introduced in the machinery industry alters not only the input coefficients but is also associated with a change in the turnover period of the capital ("Umschlagsdauer des Kapitals") which is employed in this industry:

> 'As regards the turnover period of capital, we shall assume that the durability of the buildings as well as the necessary amounts of the stocks of coal & iron remain the same, relative to the amounts of the flows. The new machines, however, are supposed to have twice the life-time of the old ones. Thus, in order to turn over the same amount of machines (in value terms) as before the capital stock must be twice as large' (*ibid*.: 113).

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8 There is no need for a "correction" of Kähler's *scheme* Ia, as proposed by Mettelsiefen (1981, p. 150). Mettelsiefen apparently failed to notice that Kähler alters the "sum of the cost elements" from 10 to 12.

9 Alternatively, the element $a_{52}$ in matrix $\mathbf{A}_{\mathrm{II}}$ could be given as '0.17', that is, as the new numerical value of the "labour input per unit of output". However, in this case the technological profit would have to be conceived of as a surplus that is generated in the economic system, and Kähler's *scheme* III could no longer be interpreted as a closed Leontief model.

A comparison of the capital stock figures in tables I and III shows that Kähler does not assume a doubling of the life-time of all machines, but only of those which are employed in the machine-producing industry.[10] This implies that in the new depreciation matrix $\mathbf{D}_{II}$ the coefficient $d_{22}$ (which shows the depreciation of machines in the machine-producing industry) must be changed from o,2 to o,1; all the other elements remain the same. For the new matrix of the capital stocks per unit of output, $\mathbf{K}_{II}$, we then have:

$$\mathbf{K}_{II} = \begin{pmatrix} 0,013 & 0,083 & 0,072 & 0,024 & 0,03 \\ 0,5 & 1,66 & 0,5 & 0,368 & 0,2 \\ 0,8 & 0,83 & 0 & 1,23 & 2 \\ 0,01 & 0 & 0,07 & 0,1 & 0,01 \\ 0,06 & 0,03 & 0,5 & 0,38 & 0 \end{pmatrix}.$$

This change in the turnover period of the machinery industry's capital stock is of crucial importance for Kähler's calculation of the labour displacement effect, because he calculates this effect – following Ricardo – on the basis of a *given amount of capital*:

> 'The initial *scheme* I contained ... 3113 capital units. This amount of capital must also suffice for the new technique, at least in the beginning. ... The following circular flow calculation (*scheme* II) shows the associated numerical values, and it is only into this structure with these relations of the numerical values that the economic circular flow can be transformed by the technical progress' (*ibid*.: 114).

In *scheme* II all the flow and stock magnitudes of *scheme* III are reduced proportionally, so that the total amount of capital is equal to the initial capital stock of 3113 units. The result of this calculation is a (hypothetical) labour displacement in the amount of 199 labour units. The main reason for this displacement is the fact that the introduction of the new method is associated with a lengthening of the turnover period of capital: with the same total stock of productive capital *in value terms* the flow of capital that can annually be "turned over" will be smaller, and therefore only a smaller number of workers can be equipped with complementary capital.

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[10] The new method of production changes only the utilization period of the machines which are employed in the machinery industry. The type of technical progress contemplated by Kähler is thus a sector-specific process innovation.

***Scheme* II**

(= scheme III, reduced to the initial capital stock)

| Inputs | Flows and stocks in the production of | | | | | | | | | | | | Total Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coal & Iron* | | *Machines* | | *Buildings* | | *Agriculture* | | *Labour* | | *Profits* | | |
| | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | |
| *Coal & Iron* | 88,2 | 5,8 | 180,3 | 30 | 35 | 25,2 | 55 | 13,5 | 80 | 24 | 3 | 0,9 | 441 |
| *Machines* | 44,1 | 218,6 | 60 | 600 | 35 | 173 | 55 | 202,5 | 160,2 | 160 | 6 | 6 | 360 |
| *Buildings* | 44,1 | 350,3 | 30 | 300 | | | 110 | 674,1 | 160,2 | 1600 | 6 | 60 | 350 |
| *Agriculture* | 44,1 | 5 | | | 35 | 25,8 | 55 | 59,1 | 400,6 | 8 | 15 | 0,3 | 550 |
| *Labour* | 220,9 | 24,3 | 60 | 11,5 | 245,3 | 177,4 | 275 | 210,8 | | | | | 801 |
| *Profit* | | | 30 | 5,7 | | | | | | | | | 30 |
| ***Total Production*** | 441 | 604 | 360 | 948 | 350 | 401 | 550 | 1160 | 801 | 1792 | 30 | 67 | |
| Total stock of productive capital = 3113, Total Wages = 801, Productive Capital : Total Wages = 3,88. | | | | | | | | | | | | | |

**(*iii*) *Compensation phase.*** *Scheme* III is meant to depict the situation at the end of the compensation phase, during which the total stock of productive capital is increased by the continuous investment of the technological (extra) profits, which emerge as long as the former prices and wages prevail. Kähler assumes that the total amount of the annually accruing (extra) profits is used for capital accumulation. With annual total profits in the amount of 30,5 units, and an average capital intensity of 3,88, this implies that '... after one year employment opportunities for 30,5 : 3,88 = 7,75 labour units will have been newly created. But additional employment opportunities are required for 199 labour units, so that ... we arrive at a compensation period of roughly 25 years' (*ibid*.: 122).[11]

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[11] Kähler seems to overlook that through the continuous accumulation of capital not only the total stock of productive capital but also the profits that accrue annually must increase. If we incorporate the growth factor, the compensation period reduces to approximately 23 years.

***Scheme* III**
(= final scheme with a sufficiently large capital stock)

| **Inputs** | **Flows and stocks in the production of** | | | | | | | | | | | | **Total flow** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coal & Iron* | | *Machines* | | *Buildings* | | *Agriculture* | | *Labour* | | *Profit* | | |
| | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | |
| *Coal & Iron* | 110,3 | 7,3 | 225,1 | 37,4 | 43,7 | 31,5 | 68,6 | 16,9 | 100 | 30 | 3,7 | 1,2 | 551 |
| *Machines* | 55,1 | 273,4 | 75 | 750 | 43,7 | 213,8 | 68,6 | 252,8 | 200 | 200 | 7,5 | 7,5 | 450 |
| *Buildings* | 55,1 | 437,5 | 37,5 | 375 | 0 | 0 | 137,2 | 842,5 | 200 | 2000 | 7,5 | 75 | 437 |
| *Agriculture* | 55,1 | 6,3 | 0 | 0 | 43,7 | 31,5 | 68,6 | 73,7 | 500 | 10 | 18,7 | 0 | 686 |
| *Labour* | 275,7 | 30,5 | 75 | 14,4 | 306,1 | 221,2 | 343,1 | 263,1 | | | | | 1000 |
| *Profit* | | | 37,5 | 7,2 | | | | | | | | | 37,5 |
| ***Total Production*** | 551 | 755 | 450 | 1184 | 437 | 498 | 686 | 1449 | 1000 | 2240 | 37,5 | 83 | |
| Total stock of productive capital = 3886, Total wages = 1000, Productive capital : Total wages = 3,88. | | | | | | | | | | | | | |

Comparing tables II and III, it is easily recognized that Kähler simply supposes a proportionate growth of all sectors during the accumulation phase, until the total stock of productive capital is sufficient for the employment of the original 1000 labour units. It would clearly be more sensible to assume an *unsteady* growth of the different sectors, because the extra profits to be reaped in the machine producing industry provide an incentive for the investment of additional capital in this sector. This would lead to an increased supply of machines, a fall in the price of machines, and thus to the emergence of technological extra profits in the *machine using industries*. Non-proportional sectoral net investments (and, perhaps, intersectoral capital movements) would then bring about a tendency towards a uniform profitability of capital in all industries.

Kähler recognizes that a proper dynamic analysis would have to take these simultaneous adjustments of prices and quantities into account. However, in order to simplify the analysis, he adopts a two-step procedure for his analysis of the adjustments of quantities and prices. In the first step, he assumes that the old price system remains valid throughout the compensation phase. This implies that the phenomenon of the economic obsolescence of (part of) the existing capital stock cannot be taken into account. Kähler is aware of this fact. He maintains that the incorporation of this aspect would generally result in the emergence of additional labour displacement:

> ‘The capital stock that exists in a specific physical form cannot simply be transformed into a new use form after an invention. This fact slows down the introduction of technical progress. ... But it also entails a great danger. If the new inventions are sufficiently productive they can make the old equipment completely obsolete. ... The emergence of labour displacement would then not only result from the increase in the capital intensity, but would also result from the destruction of the real capital that has been made obsolete’ (*ibid*.: 139).

***(iv) Price adjustments and redistribution of productivity gains.*** The final step of Kähler's analysis comprises the redistribution of the productivity gains, the establishment of a new system of relative prices, and the associated revaluation of the capital stock. Kähler argues that with the attainment of the full employment level (of the original 1000 labour units) the increased competition for workers will raise the real wage rate, until the technological extra-profits have finally disappeared. He therefore determines a new stationary equilibrium in which the technological extra-profits have been eliminated by wage rises (*scheme* IV). With the elimination of the technological extra-profits in the machinery industry (that is, with the establishment of a new uniform rate of profits at $r = 0$) the new technique must give rise to a new system of relative prices:

> 'As long as the profits exist, the 1000 units of labour must receive 1000 commodity units (in the old sense). But after the elimination of profits they must receive 37,5 units in addition. In the new scheme without profits one would therefore either have to raise the value of labour or reduce the value of each of the commodity units from 1037,5 to 1000. ... But the devaluation of the commodities can of course not be uniform, because the productivity increase affects directly only the production of machines. However, if we devalue the machines, then we automatically also devalue all the products in whose production the machine is used. On our assumptions, the values of *all* the commodities would be affected, and the more so the larger is the proportion of machines in their production costs. But if, for instance, the value of coal is reduced, then also all the commodities that are produced by coal are reduced in value, and so on. We have calculated these reductions in the values of the commodities *by means of a general system of equations*, in which now 1000 units of labour are equal in value to 103,7 original units of coal + 207,5 units of machines + 207,5 units of buildings + 518,7 units of agricultural products' (*ibid*.: 123; emphases added).

***Scheme* IV**
(= scheme III, adjusted to the new exchange relations)

| | **Flows and stocks in the production of** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coal & Iron* | | *Machines* | | *Buildings* | | *Agriculture* | | *Labour* | | |
| **Inputs** | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | Flow | Stock | ***Total*** |
| *Coal & Iron* | 108,3 | 7,2 | 221 | 36,7 | 42,9 | 31 | 67,3 | 16,6 | 101,8 | 29,4 | 541 |
| *Machines* | 48,9 | 242,7 | 66,6 | 666 | 38,8 | 189,9 | 60,9 | 224,4 | 184,2 | 177,6 | 399 |
| *Buildings* | 54,3 | 430,7 | 36,9 | 369,2 | | | 135,1 | 829,7 | 204,3 | 1970 | 430 |
| *Agriculture* | 54,1 | 6,1 | | | 42,9 | 30,9 | 67,3 | 72,4 | 509,4 | 9,8 | 673 |
| *Labour* | 275,7 | 30,3 | 75 | 14,1 | 306,1 | 221,2 | 343,1 | 263 | | | 1000 |
| ***Total Production*** | 541 | 717 | 399 | 1086 | 430 | 473 | 673 | 1406 | 1000 | 2186 | |
| Total stock of productive capital = 3682, Total wages = 1000, Productive capital : Total wages = 3,68. | | | | | | | | | | | |

Kähler's new *scheme* IV can be interpreted as follows. The normalization of the initial scheme, that is, the normalization

$$w = \mathbf{p}^T \mathbf{c} = \mathbf{p}^T (0.1, 0.2, 0.2, 0.5)^T = 1$$

is replaced by the new normalization

$$\tilde{w} = \tilde{\mathbf{p}}_{\mathrm{IV}}^T \tilde{\mathbf{c}} = \tilde{\mathbf{p}}_{\mathrm{IV}}^T (0.1037, 0.2075, 0.2075, 0.5187)^T = 1.$$

With the elimination of the technological extra-profits there is a (proportionate) increase in the quantity of each component of the workers' consumption bundle, denoted by vector $\tilde{\mathbf{c}}$. This yields a new matrix of production and consumption coefficients

$$\mathbf{A}_{\mathrm{IV}} = \begin{pmatrix} 0.2 & 0.5 & 0.1 & 0.1 & 0.1037 \\ 0.1 & 0.17 & 0.1 & 0.1 & 0.2075 \\ 0.1 & 0.08 & 0 & 0.2 & 0.2075 \\ 0.1 & 0 & 0.1 & 0.1 & 0.5187 \\ 0.5 & 0.17 & 0.7 & 0.5 & 0 \end{pmatrix}.$$

From $\tilde{\mathbf{p}}_{\mathrm{IV}}^T (\mathbf{I} - \mathbf{A}_{\mathrm{IV}}) = 0$ and $(\mathbf{I} - \mathbf{A}_{\mathrm{IV}})\mathbf{x}_{\mathrm{IV}} = 0$, the new prices and quantities are determined as $\tilde{\mathbf{p}}_{\mathrm{IV}}^T$ = (0.982, 0.888, 0.985, 0.982, 1) and $\mathbf{x}_{\mathrm{IV}}^T$ = (551, 450, 437, 686, 1000). It should be noted that the numerical values in Kähler's scheme IV – unlike those in schemes I, II and III – can no longer be interpreted as quantity magnitudes.[12]

## 4. The model of Leontief and Duchin (1986)

This section briefly compares the model developed by Kähler with the one that was recently employed by Leontief and Duchin in their empirical input output study *The Future Impact of Automation on Workers* (1986).[13] The theoretical core of the study by Leontief and Duchin consists of a dynamic input-output model, in which the sectoral amounts of investment are determined endogenously for each period, while all the other components of final demand, i.e. household consumption, government consumption and exports, are determined exogenously. It is a pure quantity model, which is first solved for the output vector $\mathbf{x}(t)$; then the vector of labour requirements by occupation, $\mathbf{e}(t) = \mathbf{L}(t)\mathbf{x}(t)$, is computed for each year (cf. Leontief and Duchin 1986: 132-8).

The Leontief-Duchin study applies a *scenario technique*: The authors first compute the employment path for a reference scenario (S1), which assumes no technical progress after a cer-

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12 Mettelsiefen (1983: 239-42) misinterprets Kähler's approach to the calculation of the new price system and (incorrectly) criticizes him for having introduced an *ad hoc* transformation of the production coefficients in his *scheme* IV (*ibid*.: 242).

13 For two other recent empirical input-output studies which investigate the impact of automation on workers, see OIW (1981) and Kalmbach and Kurz (1992).

tain base year (1980), and then various other scenarios (S2, S3, S4) are computed with different assumptions about the speed of technological change and/or the development of final demand (cf. Leontief and Duchin 1986: 5-12).

What are the major differences with regard to Kähler's study? The major advantages of the Leontief-Duchin model are the following: First, the dynamic input-output model allows to determine the time path of output and employment. Second, the application of the scenario technique allows to test the robustness and sensitivity of the results by comparing the implications of various alternative assumptions. The major shortcoming of the Leontief-Duchin model is the lack of a price model. For this reason there is no analysis of the choice of technique problem and no analysis of the impact of the technological change on prices and income distribution.

## 5. Conclusion

In his pioneering study of 1933 Alfred Kähler integrated the classical theory of labour displacement and compensation with the analysis of the circular flow. His major analytical contribution consisted in the elaboration of a multi-sectoral model of the economy as a basis for the analysis of the employment effects of new technologies. Kähler sought to capture these effects by means of a "dynamic" sequence of different (static) input-output tables, which were meant to depict the economic system in different phases of the transition from an "old" to a "new" technique. That this is the appropriate theoretical and methodical framework is confirmed by the recent development of several empirical input output studies that seek to investigate the future impact of automation on workers on the basis of dynamic input-output models.

## ***References***


Burchardt, F. (1931-32), Die Schemata des stationären Kreislaufs bei Böhm-Bawerk und Marx, *Weltwirtschaftliches Archiv*, **34**, pp. 525-64, and **35**, pp. 116-76.

Hagemann, H. (1998), Entry "Kähler, Alfred", in H. Hagemann and C.-D. Krohn (eds), *Handbuch der deutschsprachigen wirtschaftswissenschaftlichen Emigration*, Munich: Saur.

Kähler, A. (1933), *Die Theorie der Arbeiterfreisetzung durch die Maschine. Eine gesamtwirtschaftliche Abhandlung des modernen Technisierungsprozesses*, Greifswald: Julius Abel.

Kähler, A. (1935), The Problem of Verifying the Theory of Technological Unemployment, *Social Research*, **2**, 439-60.

Kalmbach, P. and Kurz, H. D. (1992), *Chips and Jobs. Zu den Beschäftigungswirkungen programmgesteuerter Arbeitsmittel*, Marburg: Metropolis Verlag.

Leontief, W. (1928), Die Wirtschaft als Kreislauf, *Archiv für Sozialwissenschaft und Sozialpolitik*, **60**, pp. 577-623.

Leontief, W. (1953), *Studies in the Structure of the American Economy*, New York: Oxford University Press.

Leontief, W. and Duchin, F. (1986), *The Future Impact of Automation on Workers*, New York: Oxford University Press.

Lowe, A. (1955), Technological Unemployment Reexamined, in G. Eisermann (ed.), *Wirtschaft und Kultursystem. Festschrift für A. Rüstow*, Stuttgart, Zürich, pp. 229-54.

Lowe, A. (1976), *The Path of Economic Growth*, Cambridge: Cambridge University Press.

Marx, K. (1954 [1867]), *Capital*, vol. I. Moscow: Progress Publishers. English translation of *Das Kapital*, vol. I (1867), Hamburg: Meissner.

Marx, K. (1959 [1894]), *Capital*, vol. III, Moscow: Progress Publishers. English translation of *Das Kapital*, vol. III, Hamburg, 1894: Meissner.

Marx, K. (1971 [1861-3]), *Theories of Surplus Value*, Part 3, Moscow: Progress Publishers. English translation of *Theorien über den Mehrwert*, Part 3, Berlin, 1962: Dietz.

Mettelsiefen, B. (1981), *Technischer Wandel und Beschäftigung. Rekonstruktion der Freisetzungs- und Kompensationsdebatten*, Frankfurt, New York: Campus.

Mettelsiefen, B. (1983), Der Beitrag der 'Kieler Schule' zur Freisetzungs- und Kompensationstheorie, in: H. Hagemann and P. Kalmbach (eds), *Technischer Fortschritt und Arbeitslosigkeit*, Frankfurt, New York: Campus, pp. 204-45.

Neisser, H. (1932), Lohnhöhe und Beschäftigung im Marktgleichgewicht, *Weltwirtschaftliches Archiv*, **36**, 414-55.

Neisser, H. (1942), 'Permanent' Technological Unemployment, *American Economic Review*, **32**, 50-71.

Österreichisches Institut für Wirtschaftsforschung und Österreichische Akademie der Wissenschaften (eds) (1981), *Mikroelektronik: Anwendungen, Verbreitung und Auswirkungen am Beispiel Österreichs*, Vienna and New York: Springer.

Ricardo, D. (1951-73), *The Works and Correspondence of David Ricardo*. Edited by P. Sraffa in collaboration with M. H. Dobb, 11 vols, (cited as *Works*), Cambridge: Cambridge University Press.

Sraffa, P. (1960), *Production of Commodities by Means of Commodities. Prelude to a Critique of Economic Theory*, Cambridge: Cambridge University Press.