DEN HARTOG AND TJAN'S VINTAGE MODEL AS A TOOL FOR THE DETERMINATION OF STRUCTURAL UNEMPLOYMENT: SOME CRITICAL REMARKS

BY

J. MUYSKEN AND C. H. VAN ARDENNE*

1 INTRODUCTION

In August 1974, H. den Hartog and H. S. Tjan, members of the staff of the Central Planning Bureau (CPB), The Hague, published a report on their investigations into the structural development of the demand for labour in the Netherlands.[1] The main conclusions of their research effort, based on the estimation of a vintage model with fixed coefficients, was that a structural decline in employment could be countered by increased investments, which in this case would imply ever rising costs per labour unit, or by a 'significant mitigation of the rise in the real cost of labour over a period of several years.'

In the *White Paper on the Unemployment Situation*,[2] presented by the Dutch government in March 1975, attention was paid to a CPB analysis based on the research carried out by Den Hartog and Tjan (HT). This was done 'in order to give concrete form to the exchange of thoughts in circles of government and industry on the most desirable policy for the years to come.' The government stressed that very complex problems of calculation are involved which have large margins of uncertainty.

Both the *Central Economic Plan 1975*[3] of the CPB and the *Report for the Year 1974*[4] of De Nederlandsche Bank (Dutch Central Bank) refer to the conclusions of the above-mentioned investigations with approval.

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1 H. den Hartog and H. S. Tjan, *Investeringen, lonen, prijzen en arbeidsplaatsen*, CPB Occasional Paper No. 2, The Hague, 1974.

2 Ministry of Social Affairs, *White Paper on the Unemployment Situation* (Nota inzake de werkgelegenheid), The Hague, 1975, pp. 19*ff* and Appendix I.

3 CPB, *Centraal Economisch Plan 1975*, The Hague, 1975, pp. 74–77.

4 De Nederlandsche Bank N.V., *Report for the Year 1974*, Amsterdam, 1975, p. 18.

The *Report for the Year 1974* states for instance: 'One can hold different views on parts [of the investigation], in its essence the argumentation seems hardly disputable.'

It may be clear from the above that the HT-paper has exerted an important influence upon the discussion about economic policy in so far as it concerns the solution of the unemployment problem. One may wonder, however, to what extent the HT-study can really provide a solid basis for devising an employment policy, that is, whether their arguments are indeed in essence hardly disputable. In order to answer this question we will examine the assumptions on which the model is based. Two kinds of assumptions can be distinguished. First, a set of assumptions is needed to select a specific type of model, for instance, a clay-clay vintage model as chosen by HT; in the second place, some assumptions are necessary to fit the model to the empirical data and – if possible – to make forecasts.

The first type of assumptions as made by HT will be considered in section 2. These assumptions will not be criticized, however, because we do not consider the discussion about this kind of assumptions meaningful until it turns out that the theory has to be rejected. For this reason attention is concentrated on the second kind of assumptions. In section 3 it is shown that these assumptions are chosen solely on *a priori* grounds and that their validity can not be tested by fitting the model to empirical observations. In section 4 we therefore investigate to what extent the results of the model are sensitive to the selection of other assumptions. If, for instance, HT assume on *a priori* grounds a certain variable to have a numerical value of 0.7, we shall check whether the values 0.6 or 0.8 lead to results that differ substantially from theirs.

Section 5 summarizes the main conclusions.

2 THE VINTAGE MODEL

Before discussing the vintage model involved it may be useful to pay attention to the concept of structural unemployment: for this is the kind of unemployment to be explained.

In the *White Paper on the Unemployment Situation*[5] 'structural unemployment in its broad sense' has been defined as total unemployment minus cyclical unemployment. Subtracting unemployment among those difficult to employ, seasonal unemployment and frictional unemployment defines 'structural unemployment in its narrow sense.' Within the latter a component resulting from qualitative discrepancies between supply and demand and a component arising from

5 Ministry of Social Affairs, *op. cit.*, p. 16.

a quantitative shortage of jobs can be distinguished. This quantitative component will be called 'structural unemployment.' We interpret the size of unemployment as calculated by HT as structural unemployment.

Den Hartog and Tjan use their model for the purpose of investigating whether the change in the trend value of employment in 1964 can be explained in terms of the rise in real labour costs, which has accelerated since 1964.[6] Van de Klundert also discusses the possibility of explaining structural unemployment by means of a vintage model with fixed coefficients.[7] He distinguishes three periods of structural inbalances on the labour market: period (I), which relates to the beginning of the 1950's and can be characterized by structural unemployment, period (II), which shows overemployment in the beginning of the 1960's, and period (III) in the beginning of the 1970's, characterized again by structural unemployment. In his opinion these three periods can be traced back quite clearly in the results obtained by HT.

Before arguing to what extent structural unemployment can be explained by a vintage model with fixed coefficients, we shall first summarize the characteristics of the model. It is assumed that the investment in fixed assets in a certain period induces a demand for labour proportional to the investment, while output also varies proportionally to the investment. The equipment[8] embodying the investment uses the same amount of labour and produces the same amount of output in each year of its life span. As a result of technical progress, however, the investment in the next period does not necessarily require the same amount of labour nor does it produce the same amount of output. These amounts will vary with the kind of technical progress.

Den Hartog and Tjan assume technical progress to be only of the labour-saving kind:[9] the capital-output ratio is constant over time, but new investments induce less demand for labour than previous investments. The only possibility left for substitution between capital and labour is to replace equipment of the oldest vintages by new equipment, which needs less labour. For this reason it is important to draw a distinction between the economic and the technical life span of the equipment. HT argue that, apart from physical deterioration, a piece of equipment will be used as long as the total wage sum required for its use does

6 H. den Hartog and H. S. Tjan, *op. cit.*, p. 1.

7 Th. van de Klundert, 'Structurele ontwikkelingen op de arbeidsmarkt,' *Maandschrift Economie*, XXXIX (1974), p. 86.

8 We follow den Hartog and Tjan, *op. cit.*, p. 3 in defining equipment as capital goods with industrial buildings excluded, but transport equipment included.

9 A more general view is taken by A. S. W. de Vries, 'Een fixed coefficients vintage model voor Nederland,' *Maandschrift Economie*, XXXVIII (1974), pp. 391–412.

not exceed the nominal proceeds of its products. The complete HT-model is reproduced in an appendix.

The model may demonstrate, for instance, that the economic life span of equipment is decreasing over time. If new investment cannot absorb the superfluous amount of labour, this leads to a structural drop in the demand for labour. The term 'structural' can be used here, because capacity demand for labour is involved. For this reason it is possible to determine structural unemployment by this model. In order to answer the question to what extent the model can be used to compute the size of structural unemployment in the Netherlands, one has to know whether the model describes the Dutch economic situation adequately.

Some authors have formulated *a priori* objections against the reality content of the model. De Galan[10] argues that technical progress is not an exogenous factor, but is also influenced by the situation on the labour market. Furthermore, he contends that an appropriate investment function is missing, which includes variables like the rate of return on investment and the capital structure of industry.

We consider none of these objections to be simply unfounded. These points might become useful to amend the model, once it has become clear that we have to reject the theory in its current form. We consider it not appropriate, however, to discuss these *a priori* objections before we have checked whether the theory should be accepted or not. Two kinds of criteria will be used to decide on rejection of provisional acceptation of a theory. Firstly, criteria which are often used in connection with the estimation procedure (for instance, in using the least-squares method, the value of the correlation coefficient should be sufficiently high, and the coefficient values should be significant), and secondly, criteria resulting from the predictive power of the model. It should be added that prediction is not necessarily restricted to the future: a theory may predict that the estimated value of a certain coefficient must lie between 0 and 1. One should realize that this definition of prediction includes what sometimes is referred to as testing. From our point of view this distinction between prediction and testint is irrelevant: a theory is tested by looking at its predictions (as indicated above). If the predictions turn out to be right the theory is provisionally accepted; if not, the theory is rejected.

As far as the criterion of predictive power is concerned, it should be taken into consideration that the key variables in the vintage model are not directly observable. Moreover, the model itself imposes very few restraints on the calculated

10 C. de Galan, 'De werkgelegenheidsnota,' *Economisch-Statistische Berichten*, LX (1975), p. 240.

values. One of the few possibilities left then is to compare the values calculated by the model with those found in other studies. In doing so one assumes these values to be rather good approximations of the actual values. At least two problems then arise. First, the criterion according to which these other values are considered to be a good description of reality is often only the authority of the scholar who has found these values, or the fact that approximately the same values have been found in a number of other studies. Secondly, these other values usually cover a range within which the values computed by the model must lie, but the boundaries of this interval are not fixed so that the margins of prediction can be fairly large. Because only a few persons[11] have tried to estimate a clay-clay vintage model, the opportunities for HT to compare their results with others are very rare. This does not alter the fact that one has to do with what one has; one has also, however, to try to gain better information in the future.

From the above we conclude that the criterion of predictive power offers very little possibility for rejecting or provisionally accepting the theory. In this case the criteria which are often used in connection with the estimation procedure to indicate the goodness of fit become important. In the next section the method used to fit the model to empirical data will therefore be investigated.

3 THE ESTIMATION PROCEDURE

In estimating equations the econometrician usually has at his disposal several series of observations of the various variables; in that case he can estimate the unknown coefficients in the equations by using the least-squares or any other related method. As has been pointed out in section 2, estimation criteria that refer to the degree in which the equation fits to the observed facts are often used in connection with the applied method of estimation.

One of the problems in estimating parameters in equations of vintage models is the lack of series of observed values of some essential variables, for instance, capacity output and capacity demand for labour. Furthermore, several parameters are unknown, such as:

μ the growth rate of technical progress;
φ the level of labour productivity for the vintage of 1948.

Between them μ and φ characterize the technical progress as described by the model.

Due to the lack of data it is impossible to estimate the equations in the model by means of least-squares or related methods. So another technique has to be

11 See *e.g.* R. Attiyeh, 'Estimation of a Fixed Coefficients Vintage Model of Production,' *Yale Economic Essays*, VII (1967), pp. 5–40.

devised for determining the numerical values of the unknown variables and coefficients. It should be clear, however, that it is impossible to determine these values without making particular assumptions with respect to some of them. In the appendix we have listed, as precisely as possible, the assumptions made by HT on that account. The main assumptions are:

(I) The percentages of annual physical depreciation are considered as given; after 45 years the equipment is completely worn out;

(II) An *a priori* value of 0.75 has been assigned to two parameters, namely, δ_1 and δ_2 – both coefficients correcting the number of hours worked;

(III) The annual growth rate of technical progress before the Second World War has been 25 per cent of that after the war;

(IV) The equations have been fitted for the years 1959–73;

(V) A special set of assumptions, that will be discussed later, is made with respect to the estimation criterion.

A serious disadvantage of the fact that one cannot make use of a more or less traditional estimation method is that criteria which are normally used to indicate the goodness of fit, are no longer available. For this reason it is also impossible to examine whether the particular assumptions made about the numerical values of certain unknown coefficients or parameters satisfy these criteria. In this situation it is, of course, essential that the results of the investigation should not substantially be modified by small variations in the above-mentioned assumptions. Otherwise the results are heavily dependent upon assumptions whose usefulness cannot be tested.

The HT assumptions will now be expounded, whereupon limited variations in each of them will be introduced. In the next section the effects of these limited variations on the results of the model will be investigated.

(I) HT assume that during the first six years of its existence equipment of a certain vintage will not be subject to physical deterioration. During the following thirty-nine years a certain part of the equipment disappears annually. In the course of time this part at first increases and then decreases. An alternative assumption is that this part is constant during a period of forty years, while the process of physical deterioration starts already after one year; every year 1/40 part of the equipment of a certain vintage vanishes.

(II) Possible values of the coefficients δ_1 and δ_2 other than 0.75 are, for instance, 0.70 and 0.80. Using these three values, nine alternatives can be investigated. It should be noted that De Vries (p. 392) choose $\delta_1 = 0.70$ and $\delta_2 = 1.00$. In another research paper of the Central Planning Bureau δ_1 is also assumed to have a value of 0.70.[12]

12 See J. Kooyman and A. H. Q. M. Merkies, *Possible Growth in the Netherlands up to 1985*, CPB Occasional Paper No. 1, The Hague, 1972.

(III) The growth rate of technical progress before the Second World War is supposed to be a fraction of this growth rate after the war. This fraction will henceforth be called *MUP*. HT assume $MUP = 0.25$, because – as they put it – this is about the ratio between the average increase in labour productivity before and after the war. Two obvious alternatives are $MUP = 0.20$ and $MUP = 0.30$.

(IV) Because of the availability of more recent data it is now possible to estimate the equations for the period 1959–74, which is an alternative to HT's estimation for the period 1959–73.

(V) If the numerical values of μ and φ are known, then, under the assumptions made, it is possible to determine the annual values of capacity output and of capacity labour demand, each except for a scalar. The problem is, however, to find the values of μ, φ and the scalars. In order to determine these values HT assume that in 1970 the economy was in a position of structural equilibrium: in this year capacity output and capacity labour demand were equal to actual output and employment. For the purpose of determining μ and φ, HT furthermore make the special assumption that total structural employment equals total actual employment over the period on hand. The sum of the squared deviations of calculated from actual employment over the estimation period, *SA*, is then calculated for a large number of combinations of μ and φ. In the same way the sum of the squared deviations of calculated from actual output, *SY*, is computed. Finally, the combination of μ and φ is chosen which minimizes the arithmethical product of *SA* and *SY* (alternative 5.1).

Alternative 5.1 is clearly inspired by the ordinary least-squares method, but there is nevertheless an important difference between the two. In applying the least-squares method observed values of certain variables are compared with estimated values, whereas in the method as described by HT the nature of the calculated values is very different: here calculated values are structural, whereas observed values are, of course, factual. If, nonetheless, we follow HT's reasoning at least two alternatives can be contrived. The above-mentioned special assumption can be interpreted as if in every year structural employment has been equal to actual employment. On these grounds that combination of μ and φ can be selected which minimizes solely *SA* (alternative 5.2). But on the analogy of the least-squares method, we also can minimize the sum of *SA* and *SY* instead of their arithmethical product (alternative 5.3).

HT do not adduce arguments in support of their assumption that 1970 was a year in which structural equilibrium existed. Interpreting 'a year in which structural equilibrium exists' as a year with a balanced labour market – in such a year only frictional unemployment exists, which presumably amounts to about 1.5% of the labour force – we are equally justified in considering 1960 as a year of structural equilibrium. This contention is supported by the results of HT: in 1960 the differences between actual and calculated values of output and employment are minute. Van de Klundert also puts the transition from structural unemployment to over-employment roundabout 1960. So another alternative is to take 1960 as our base year instead of 1970 (alternative 5.4).

A drawback of the above-mentioned special assumption is that – unlike the assertion by HT[13] – the level of actual employment influences the computation of structural employment. This objection can be met by replacing this special assumption by the alternative of assuming that both 1960 and 1970 were years in which the economy was in structural equilibrium. The set of combinations of values of μ and φ can then be determined for which the quotient of actual outputs in 1960 and 1970 is equal to the quotient of calculated outputs in those years. This enables us to draw a curve in a (μ, φ)-plane. It is also possible to find the set of combinations of values of μ and φ, for which the quotient of actual employment in 1960 and 1970 is equal to the quotient of calculated employment in those years. This allows us to draw a second curve in the (μ, φ)-plane. The point of intersection of these two curves then determines the ultimate values of μ and φ (alternative 5.5).[14]

4 RESULTS

4.1 *Preliminary Remarks*

In this section the results of the sensitivity analysis of the model and its estimation procedure will be expounded. The degree to which both the model and the estimation procedure are sensitive to small variations in some parameter values will be explored simultaneously in subsection 4.2.[15] We will have a closer look at several assumptions which underlie the HT-model. It will be investigated also to what extent the alternative assumptions which were formulated in section 3, will influence the results of the model.

In order to perform such a sensitivity analysis, it was necessary first to reconstruct the HT-model. Introduction of $\mu = 0.048$ and $\varphi = 9.25$, the set of parameters HT consider optimal, indeed showed the same results as those stated in their paper.

With regard to the procedure that can be used to determine the ultimate val-

13 H. den Hartog and H. S. Tjan, *op. cit.*, p. 16.

14 We owe this idea to Dr. S. K. Kuipers.

15 Obviously one should not investigate the impact of changing some parameter values without re-estimating the values of μ and φ.

ues of μ and φ, several alternatives exist as was expounded in section 3. The method, for instance, which makes use of two base years (alternative 5.5) leads to diverging results. A drawback of this method is, however, that it requires a lot of computer time. Therefore, we have limited ourselves to using this criterion only once. For the sake of brevity, the same holds for the method in which 1960 is chosen as a base year instead of 1970 (alternative 5.4).

It has also been examined to what extent the selection of $SA + SY$ as a criterion in the estimation procedure (alternative 5.3) has an impact on the model results. It should be noted that in this criterion the units of SA and SY are of major importance. As they are measured now, SY completely dominates. Both series will have a more equivalent impact if $SA + SY/100$ is chosen as a criterion: the results then hardly differ from those when $SA \cdot SY$ is used. This confirms a remark made by Van de Klundert, that 'these criteria usually do not differ widely with respect to the optimal combination of parameters.'

This leaves the alternatives 5.1 and 5.2. Alternative 5.2 – SA – has been used by HT in their procedure. The application of SA or $SA \cdot SY$, however, leads to different values of μ and φ and therefore of the computed size of structural unemployment. That is why we shall use both SA and $SA \cdot SY$ as criteria in the procedure for determining μ and φ, investigating the results of alternative assumptions in section 4.2.

4.2 *Sensitivity Analysis*

In section 3 some alternatives have been formulated for the assumptions made by HT for the purpose of estimating their model. In this section the sensitivity of the model to these alternatives will be explored. Concerning those assumptions we can list the following results.

(I) The alternative assumption concerning the path of physical deterioration, Ω, yields a different combination of optimal parameter values for μ and φ, whether we use SA or $SA \cdot SY$ as a criterion in the estimation procedure. The consequences of using this 'new' assumption are shown in Table I and Figure 1, where, on the vertical axis, the difference between calculated labour demand and the labour supply (*times* 1000 man-years) is plotted.

TABLE I – THE IMPACT OF DIFFERENT ASSUMPTIONS REGARDING Ω ON μ AND φ

	SA		*SA.SY*	
	μ	φ	μ	φ
'old'	0.049	9.35	0.056	10.45
'new'	0.047	9.90	0.058	11.95

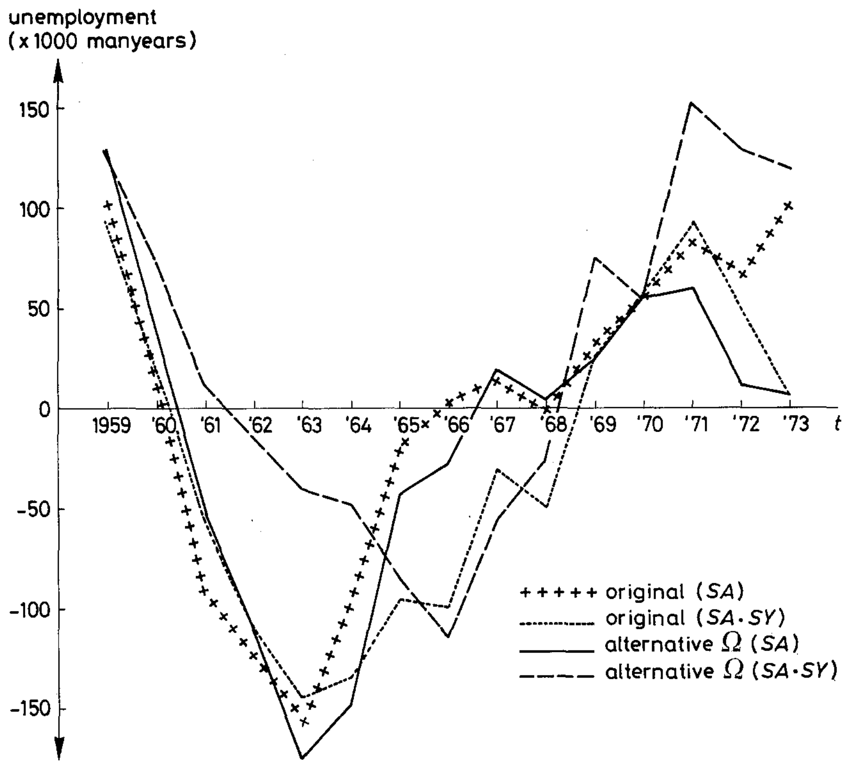

Figure 1

(II) Both δ_1 and δ_2 have been given the numerical values 0.70, 0.75 and 0.80. The introduction of these nine combinations of values of δ_1 and δ_2 turned out to have no impact at all on the values of μ and φ – as can be seen in Table II, where only two combinations are shown – and to yield results, which only slightly deviated from those obtained by HT. This is illustrated in Figure 2.

(III) Some alternatives have been formulated for the numerical value of *MUP*, the ratio of the growth rate of technical progress before the Second World War

TABLE II – THE IMPACT OF DIFFERENT ASSUMPTIONS REGARDING δ_1 AND δ_2 ON μ AND φ

	SA		*SA.SY*	
	μ	φ	μ	φ
$\delta_1 = 0.70; \delta_2 = 0.80$	0.049	9.35	0.056	10.45
$\delta_1 = 0.75; \delta_2 = 0.75$	0.049	9.35	0.056	10.45

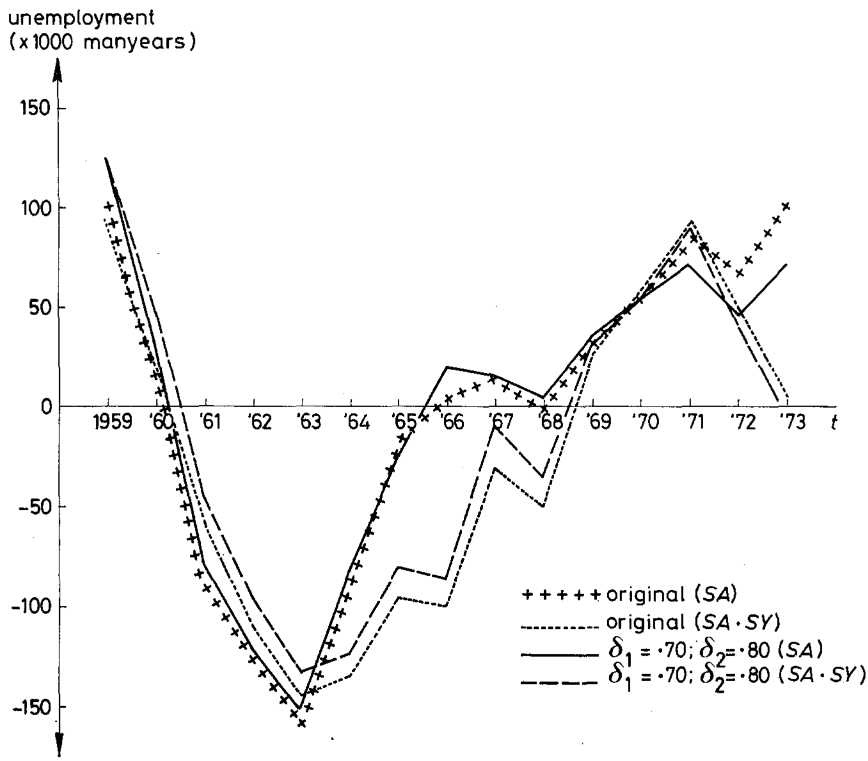

Figure 2

to its value after the war. Specification of different *MUP*-values – *MUP* = 0.20, 0.25 or 0.30 – brings about new combinations of optimal μ and φ-values, as can be seen in Table III. The consequences of these results for the volume of structural unemployment as generated by the model are shown in the Figures 3[a] and 3[b]. The effects of different values of *MUP* appear to be rather important.

(IV) The HT-model has been fitted to the data for 1959–1973. The enlargement of this estimation period by only one year to 1959–1974, already turns out to

TABLE III – THE IMPACT OF DIFFERENT ASSUMPTIONS REGARDING MUP ON μ AND φ

	SA		*SA.SY*	
	μ	φ	μ	φ
MUP = 0.20	0.052	9.70	0.054	9.95
MUP = 0.25	0.049	9.35	0.056	10.45
MUP = 0.30	0.047	9.30	0.056	10.70

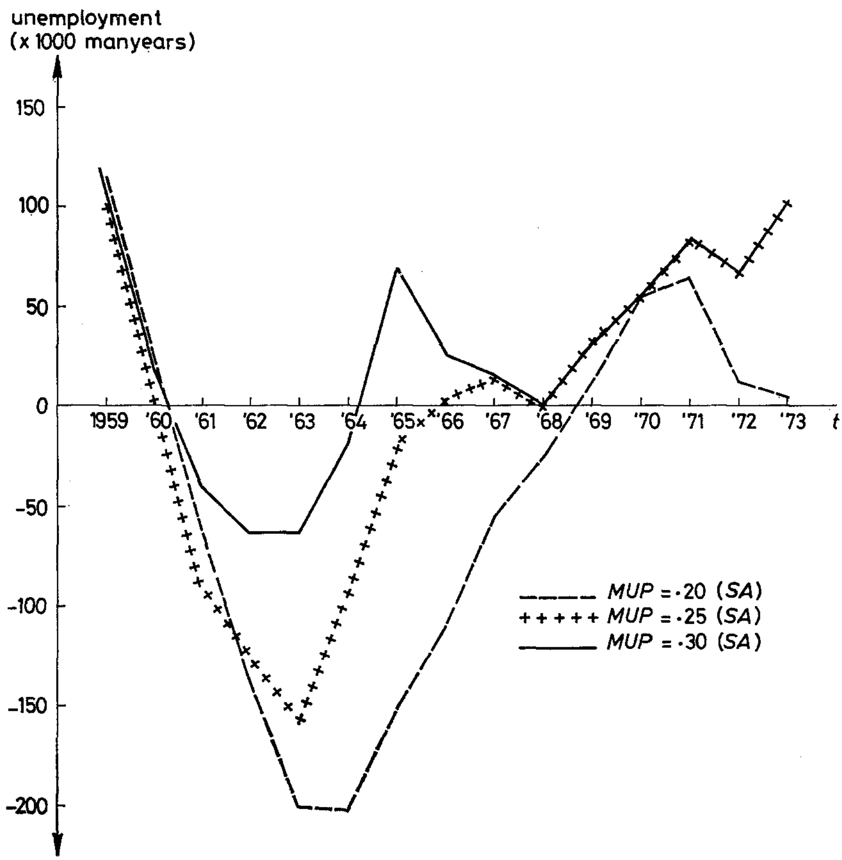

Figure 3a

have an important impact on the set of optimal parameter values and, therefore, on the results generated by the model (see Table IV and Figure 4).[16]

(V) A point that continually emerges from this sensitivity analysis is that the use of SA or $SA \cdot SY$ as criterion in the estimation procedure leads to different values of μ and φ and therefore, of the size of structural unemployment as generated by the model. The choice of the base year, however, in which 'the production apparatus can reasonably be assumed to be fully employed,' (alternative 5.4) turns out to be important too in determining the optimal μ- and φ-values. This is especially so when the criterion $SA \cdot SY$ is used. The selection of the base year has no impact when only SA is applied. This is understandable: only one series is used. The method of using two base years (alternative 5.5) leads to

16 It is remarkable that the results for the longer period are the same for both criteria. We are inclined, however, to consider this to be coincidence.

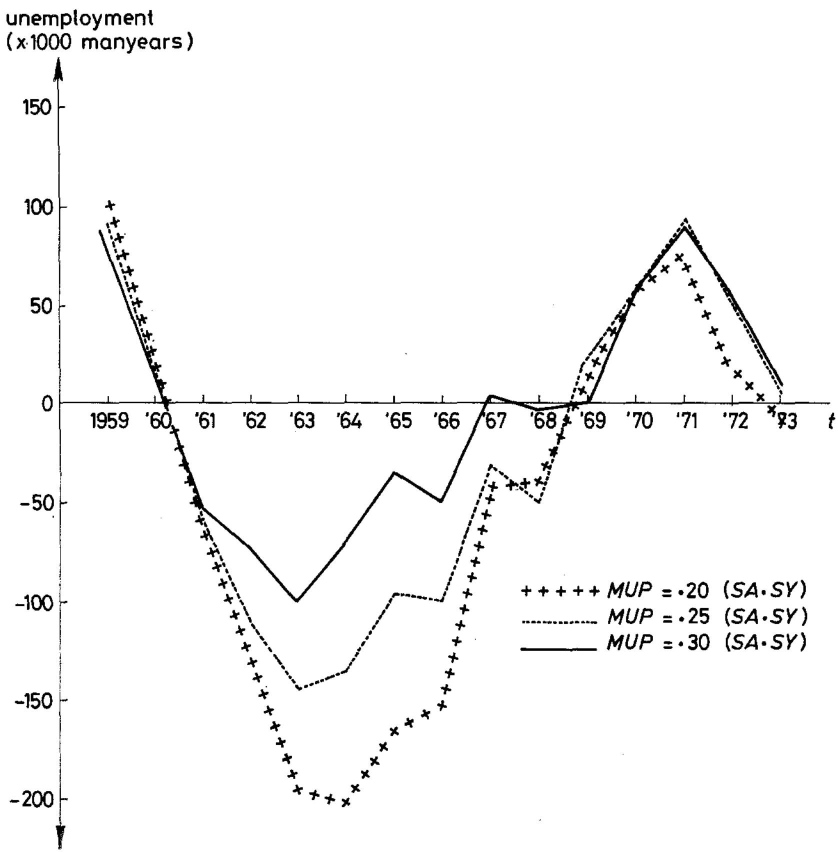

Figure 3b

TABLE IV – THE IMPACT OF DIFFERENT ESTIMATION PERIODS ON μ AND φ

	SA		*SA.SY*	
	μ	φ	μ	φ
1959–1973	0.049	9.35	0.056	10.45
1959–1974	0.052	9.85	0.052	9.85

clearly diverging results: the two curves in the (μ, φ)-plane intersect in point (μ = 0.0514; φ = 9.85).

These results of the different alternatives are presented in Table V and Figure 5.

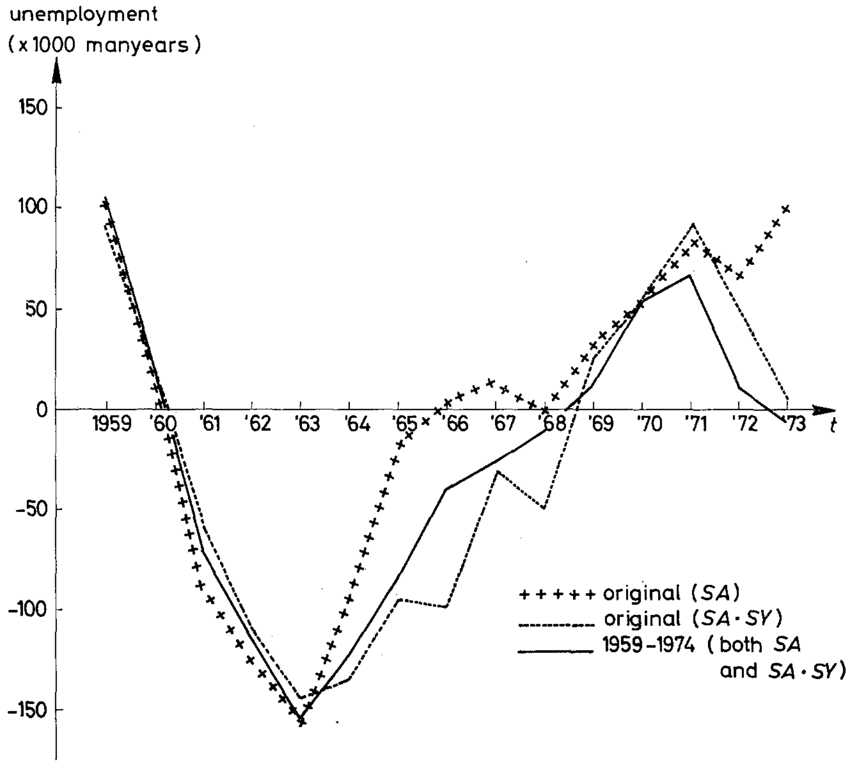

Figure 4

TABLE V – THE IMPACT OF DIFFERENT CRITERIA ON μ AND φ

	μ	φ
SA (5.2)	0.049	9.35
SA.SY (1970) (5.1)	0.056	10.45
SA.SY (1960) (5.4)	0.048	9.30
two base-years (5.5)	0.051	9.85

5 CONCLUDING REMARKS

Not much empirical research has been done yet in the area of vintage models with fixed coefficients. Den Hartog and Tjan have succeeded in solving many of the problems involved in the fitting of this kind of model to empirical data. In this respect their work should be considered as a valuable contribution. In order to reach their goal, however, they had to make a number of assumptions.

We are basically inclined to judge the value of a theory and the assumptions

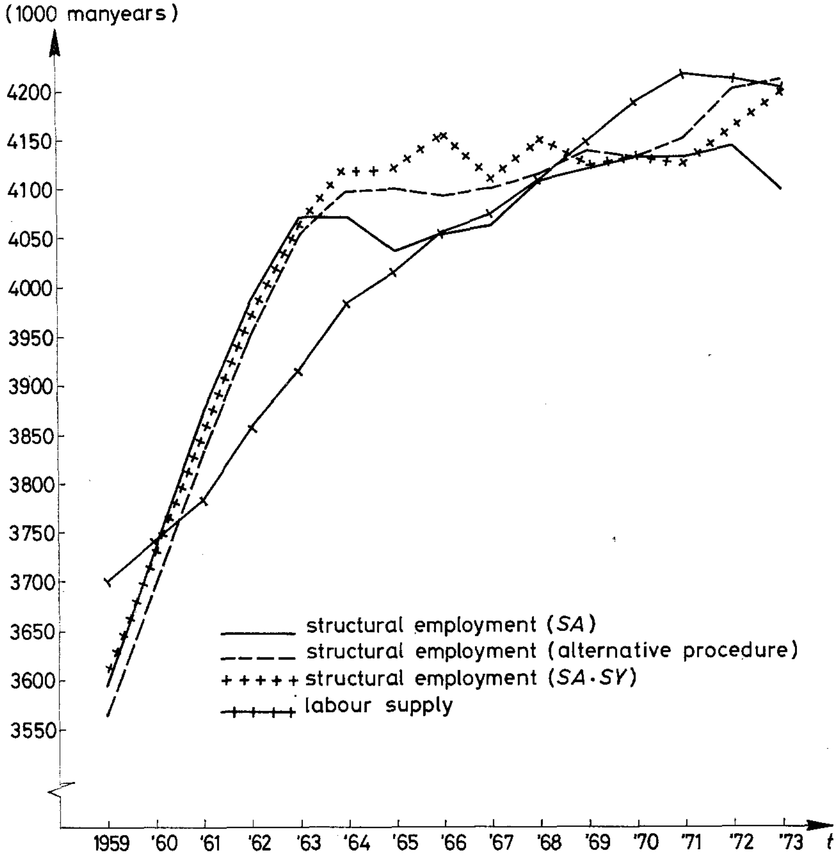

Figure 5

on which it is based according to its predictive power and the degree to which it satisfies the criteria which are often used in connection with the estimation procedure. As has been argued in section 2, it is impossible to test the predictive power of the HT-model. At best we can investigate whether the results of prior research correspond with those obtained by HT. The difficulty then is that comparable research has hardly been done until this moment. This, for that matter, further enhances the merits of HT's study. It has, however, been pointed out in section 3 that the estimation procedure does not produce clear-cut criteria for deciding whether or not the theory should be rejected.

Therefore, it is impossible for us to examine whether the theory based on the assumptions made by HT must be rejected or not.

In cases like this it is of the utmost importance that the results of the theory are not very sensitive to these assumptions; otherwise it is possible to obtain any desired result by 'cleverly' choosing the assumptions.[17] For that reason we have proposed some other sets of assumptions in section 3. Finally it has been investigated in section 4 to what extent these alternatives really affect the results of the model; unfortunately, this kind of sensitivity turned out to be rather high. Utilizing a certain set of assumptions we found that the size of structural unemployment was more than 100.000 jobs in 1973, whereas under some other assumptions it turned out that there was hardly any structural unemployment at all in that year. A clear illustration of this statement has been presented in Figure 5.

On the grounds that the margins of uncertainty of the results of the HT-study, which have been emphasized by many participants in the debate, are so very large, the question can legitimately be raised whether the results present a reliable basis for devising an effective employment policy. We are inclined to give a negative answer to this question. In our opinion it will be necessary first to supplement the theory in such a way that it is possible to formulate clear-cut criteria for deciding whether or not the theory, based as it is on a certain set of assumptions, should be rejected.

All this does not, of course, controvert the fact that the HT-study should be considered a valuable impetus to further research.

APPENDIX

THE VINTAGE MODEL WITH FIXED COEFFICIENTS

In this appendix we reproduce and elucidate the model as used by Den Hartog and Tjan. After that we will describe the HT-method for determining the numerical values of the unknown variables in the model.

The model consists of the following equations:

$$Y_{t,\tau} = \frac{1}{\kappa} \cdot h_t^{\delta_1} i_{t,\tau} \tag{1}$$

$$Y_{t,\tau} = \varphi\,(1+\mu)^{\tau-1948}\, h_t^{\delta_2}\, a_{t,\tau} \tag{2}$$

$$i_{t,\tau} = \Omega_{t-\tau}\, i_{\tau,\tau} \tag{3}$$

$$Y_{t,v_t} p_t = a_{t,v_t}\, l_t \tag{4}$$

$$Y_t = \sum_{\tau=v_t}^{t} Y_{t,\tau} \tag{5}$$

17 We are certainly not suggesting that HT are guilty of such manoeuvres.

$$a_t = \sum_{\tau=v_t}^{t} a_{t,\tau} \tag{6}$$

$$Y_t^T = Y_t + \gamma_1 Y_t \tag{7}$$

$$a_t^T = a_t + \gamma_2 a_t \tag{8}$$

Equation (1) explains capacity output in year t by equipment from year τ in terms of the inverse capital-output ratio (assumed to be constant), the index of working hours corrected for the existence of continuously operated industry, and the amount of equipment of vintage τ in operation. Equation (2) explains this capacity output in terms of labour-saving technical progress (where φ denotes the level of labour productivity in 1948), the corrected index of working hours and the manpower needed for handling the equipment of vintage τ still in use. Equation (3) shows the fraction of equipment installed in year τ, which is not yet written off. Equation (4) reflects the assumption that the oldest vintage still in use, v_t, is determined by the possibility to cover labour-costs with the proceeds of its output. So the economic life span of the oldest equipment equals $t - v_t$. Equations (5) and (6) define capacity output in a certain year t and the labour input that goes with it, respectively.

Equation (7) displays the idea that the capacity output of total industry is the sum of the capacity output of the sector using equipment and labour, and that of a complementary sector which uses only labour. Equation (8) demonstrates the same assumption for capacity labour demand.

From the equations (1) – (8), it can be deduced that:

$$v_t = 1948 + \frac{\ln\left(\frac{l_t}{p_t}\right) - \delta_2 \ln(h_t) - \ln(\varphi)}{\ln(1+\mu)} \tag{9}$$

$$Y_t^T = \frac{1+\gamma_1}{\kappa} h_t^{\delta_1} \cdot \sum_{\tau=v_t}^{t} \Omega_{t-\tau} I_{\tau,\tau} \tag{10}$$

$$a_t^T = \frac{1+\gamma_2}{\kappa} \frac{1}{\varphi} h_t^{\delta_1-\delta_2} \sum_{\tau=v_t}^{t} \left[\Omega_{t-\tau} \frac{i_{\tau,\tau}}{(1+\mu)^{\tau-1948}} \right] \tag{11}$$

The HT model is thereby reduced to the equations (9) – (11). Empirical values of Y_t^T, a_t^T, v_t and $\Omega_{t-\tau}$ are lacking for each year. The unknown parameters are μ, φ, δ_1, δ_2, $(1+\gamma_1)/\kappa$ and $(1+\gamma_2)/(1+\gamma_1)$. Finally, the known variables are $l_t, p_t, h_t, i_t, \tilde{Y}_t$ and $\tilde{a}_t$.

It will be clear that none of the equations (9) – (11) can be estimated directly. In order to determine the values of the unknown variables it is therefore necessary to make complementary assumptions and to decide on a criterion in accordance with which these values can be computed. The establishment of this criterion will be labelled the 'estimation procedure.'

HT have made the following complementary assumptions:

(1) The fractions of annual technical depreciation, and thereby of annual technical survival $\Omega_{t-\tau}$, behave in accordance with a pre-determined series, ranging over a 45-year period;

(2) δ_1 has *a priori* been given the value of 0.75;

(3) δ_2 has *a priori* been given the value of 0.75;

(4) The production apparatus is fully utilized in 1970, so $Y_{1970} = \tilde{Y}_{1970}$ and $a_{1970} = \tilde{a}_{1970}$;

(5) The rate of technical progress before the Second World War is a quarter of its value after the war, when the year of transition is 1948;

(6) No technical depreciation occurs in the period 1940–1947. As a result of the war, 34.54% of the existing capital stock has been destroyed between 1940 and 1943;

(7) Capacity labour demand equals actual employment over the total estimation period (we will come back to this later);

(8) The effect of the real labour costs (l/p) in eq. (9) has a lag of six months.

Using the assumptions (1) – (6) we can determine $(1 + \gamma_1)/\kappa$ and $(1 + \gamma_2)/(1 + \gamma_1)$ and also the numerical values of Y_t^T and a_t^T in each year for a certain set values of μ and φ. This is done by introducing the values of μ and φ into equation (9) and then computing the vintage of the oldest equipment in use v_t. Then $(1 + \gamma_1)/\kappa$ and $(1 + \gamma_2)/(1 + \gamma_1)$ can be calculated according to equations (12) and (13) respectively:

$$\frac{1 + \gamma_1}{\kappa} = \tilde{Y}_{1970} \Bigg/ \left[h_{1970}^{\delta_1} \sum_{\tau = v_{1970}}^{1970} \Omega_{(1970-\tau)} \cdot i_{\tau,\tau} \right] \tag{12}$$

$$\frac{1 + \gamma_2}{1 + \gamma_1} = \tilde{a}_{1970} \Bigg/ \left[\frac{1 + \gamma_1}{\kappa} \cdot \frac{1}{\varphi} h_{1970}^{\delta_1 - \delta_2} \sum_{\tau = v_{1970}}^{1970} \Omega_{(1970-\tau)} \cdot \frac{i_{\tau,\tau}}{(1 + \mu)^{\tau}} \right] \tag{13}$$

The annual values of Y_t and a_t can then be determined from equations (10) and (11).

This leaves us with the problem how to determine the numerical values of μ and φ: at least two criteria can be mentioned. That combination of μ and φ-values that minimizes $SA \cdot SY$ or the combination that minimizes SA can be used as a criterion, *i.e.*

$$\sum_{t=1959}^{1973} (a_t^T - \tilde{a}_t)^2 \cdot \sum_{t=1959}^{1973} (Y_t^T - \tilde{Y}_t)^2 \quad \text{or} \quad \sum_{t=1959}^{1973} (a_t^T - \tilde{a}_t)^2 \tag{14}$$

It should be noted that the value of $(1 + \gamma_2)/(1 + \gamma_1)$, which we need for calculating a_t, is not determined by equation (13) but, by using assumption 7, as follows:

$$\frac{1 + \gamma_2}{1 + \gamma_1} = \left(\sum_{t=1959}^{1973} \tilde{a}_t \right) \Bigg/ \left[\frac{1 + \gamma_1}{\kappa} \cdot \frac{1}{\varphi} \sum_{t=1959}^{1973} h_t^{\delta_1 - \delta_2} \sum_{\tau = v_t}^{t} \left(\frac{\Omega_{(t-\tau)} \cdot i_{\tau,\tau}}{(1 + \mu)^{\tau}} \right) \right] \tag{15}$$

When the μ and φ-values as determined in accordance with criterion (14) are found, the fraction $(1 + \gamma_2)/(1 + \gamma_1)$ is calculated in accordance with eq. (13).

This value is used in the computation of the final time series for a_t.

LIST OF SYMBOLS

a_t capacity demand for labour in the sector using both equipment and labour;
$\tilde{a}_t$ actual total labour input;
a_t^T total capacity demand for labour;
$a_{t,x}$ labour necessary in year t to man the equipment still in use of vintage x;
h_t index of working hours in year t;
$i_{t,x}$ equipment of vintage x which is still in use in year t;
$i_{x,x}$ investments in equipment in year x;
l_t wage rate per man-year in year t;
p_t price of output in year t;
Y_t capacity output of the sector using both equipment and labour;
$\tilde{Y}_t$ actual total output;
Y_t^T total capacity output;
$Y_{t,x}$ capacity output in year t of the equipment still in use of vintage x;
γ_1 complementarity factor with respect to capacity output;
γ_2 complementarity factor with respect to capacity demand for labour;
δ_1 elasticity of production with respect to working hours in the relation between capacity output and investment;
δ_2 elasticity of production with respect to working hours in the relation between capacity output and capacity-demand for labour;
κ capital-output ratio;
μ growth rate of embodied labour-saving technical progress;
v_t vintage of the oldest equipment still in use in year t;
φ level of labour productivity of equipment of 1948;
Ω_{t-x} survival fraction of the equipment after $(t - x)$ years.

Summary

DEN HARTOG AND TJAN'S VINTAGE MODEL AS A TOOL FOR THE DETERMINATION OF STRUCTURAL UNEMPLOYMENT: SOME CRITICAL REMARKS

The use of the vintage model with fixed coefficients as devised by den Hartog and Tjan for determining the causes of structural unemployment, is scrutinized; one should realize that this model had a great impact on the analysis of the unemployment situation by the Dutch government. On methodological grounds a sensitivity analysis of the model is performed and it is argued that the margins of uncertainty adhering to the results of this model are so large as to make the model in its current form a very questionable basis for an effective policy.