4 Employment and Unemployment in the Netherlands, 1960–84: A Putty–Clay Approach*

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4.1 INTRODUCTION

Since the mid-1970s vintage models have played an important role in the analysis of the Dutch economy.1 Although earlier vintages of these models were of a clay–clay nature, technical progress in economic analysis and in estimation methods enabled more recent vintages to be of a putty–clay nature. Examples of the latter are Kuipers and van Zon (1982) and Gelauff, We. nekes and de Jong (1985). We shall further refer to them as KvZ and GWJ, respectively. Our model fits in with this putty–clay tradition. However, before highlighting several features of our model, some general remarks should be made.

In the period 1950–70 employment in the private sector in the Netherlands increased from 3400 to 4130 thousand man–years. It remained at a more or less constant level of 4100 thousand man–years till 1980 and then decreased rapidly to a level of 3800 thousand in 1983, at which it remained for the years 1984 and 1985. Likewise, unemployment increased slowly from 70 thousand man–years in 1970 to 325 thousand man–years in 1980. Then unemployment accelerated towards a level of 800 thousand man–years in 1983, at which it remained for the years 1984 and 1985. The unemployment rate is nowadays about 17 per cent. Muysken and Meijers (1985) explain that the earlier developed clay–clay vintage models cannot adequately deal with these turbulent developments in the period 1980–5. With respect to the putty–clay models, KvZ estimate their model for the period 1950–77 and GWJ for the period 1960–82. As we shall explain later on, their models do not describe the aforementioned turbulent developments adequately. Moreover, although investment is in

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principle endogenous in a putty–clay model, as it is in a clay–clay model, both KvZ and GWJ treat it as an exogenous variable. Finally, while KvZ do not distinguish explicitly between demand for labour and employment in discussing unemployment, GWJ do not discuss employment or unemployment at all and only explain demand for labour.

As we explain in section 4.2, investment is an endogenous variable. Furthermore, demand for labour and employment are distinguished explicitly. For that purpose an employment function is introduced into the analysis. Finally, both employment and scrapping of equipment are dealt with in different ways. Whereas all previous vintage models assume that all equipment is utilised at the same utilisation rate once it has been installed, we assume that equipment is utilised at full capacity in decreasing order of efficiency. Hence, when aggregate demand is below full-capacity output, equipment of least efficient vintages is laid-off. This also leads to labour hoarding, which is explicitly incorporated into the model. As a consequence, vintages can also be scrapped when they have not been used for several years even though they have a positive quasi-rent: Apart from economic obsolescence we also allow for obsolescence caused by excess capacity.

In section 4.3 we estimate the parameters of the model for the period 1960–82 and, in order to check the reliability of the results, forecast for the years 1983 and 1984. We use the results to analyse unemployment, distinguishing between structural unemployment (of both a qualitative and a quantitative nature) on the one hand, and cyclical unemployment on the other.

Finally, some concluding remarks are made in section 4.4.

4.2 THE MODEL

The Production Structure ex ante

The production structure ex ante in year $T$ is described by means of a linearly homogeneous CES-function with both capital- and labour-augmenting technical progress. The function is:

$$X_{t,T} = [(A \cdot (1 + \mu_n)^T \cdot h_{it} \cdot N_{t,T})^{-\rho} + (B \cdot (1 + \mu_s)^T \cdot h_{it} \cdot I_{t,T})^{-\rho}]^{-1/\rho}$$

(4.1)

where $X_{t,T}$, $N_{t,T}$ and $I_{t,T}$ stand for productive capacity, labour and
investment of vintage $T$ in year $t$, respectively. Since labour is expressed in man–years, $N_{T,T}$ is corrected by an index for effective working hours, $h_{n,T}$. As a consequence, investment is also corrected by an index for effective working hours, $h_{I,T}$. Embodied labour and capital augmenting technical progress are expressed by the parameters $\mu_n$ and $\mu_I$, respectively. Disembodied technical progress shows up in the production structure *ex post*. The elasticity of substitution is $\sigma = 1/(1 + \rho)$.

We assume that behaviour of entrepreneurs can be described as follows. Expecting a certain need for capacity ($X_{T,T}$), man–years ($N_{T,T}$) and capital ($I_{T,T}$) are chosen as to maximise the present value of expected rent of equipment of vintage $T$ over its expected lifetime, $P_T$. That is:

$$\Phi = \sum_{t=T}^{T+T} \left\{ p^e(t)_{T,T} \cdot \frac{X_{T,T} - w^t(t)_{T,T} \cdot N_{T,T}}{(1 + r^t(t)_{T,T})^{t-T}} - p_T^t \cdot I_{T,T} \right\}$$

(4.2)

is maximised subject to (4.1). In equation (4.2) $p^e(t)_{T,T}$, $w^t(t)_{T,T}$ and $r^t(t)_{T,T}$ represent expectations of output prices, wages (wage sum per man–year) and the rate of interest in year $t$, respectively, formed in year $T$. $p_T^t$ stands for the price of investment.

As can be seen from equation (4.2), the choice of a certain production technique from the production function *ex ante*, requires information both about the production structure *ex post* and about expectations with respect to output, lifetime and factor prices. We first discuss the production structure *ex post*.

**The Production Structure *ex post***

It is assumed that once the machines of vintage $T$ have been installed, substitution between labour and capital is no longer possible. Nonetheless, both labour productivity and capital productivity of that vintage will change over time for two reasons: changes in effective working hours and in disembodied technical progress. This can be expressed as follows:

$$\frac{X_{T,T}}{N_{T,T}} = \frac{h_n}{h_{n,T}} \cdot (1 + \gamma_n)^{t-T} \cdot \frac{X_{T,T}}{N_{T,T}}$$

(4.3)

$$\frac{X_{T,T}}{I_{T,T}} = \frac{h_I}{h_{I,T}} \cdot (1 + \gamma_I)^{t-T} \cdot \frac{X_{T,T}}{I_{T,T}}$$

(4.4)
where $\gamma_a$ and $\gamma_i$ stand for labour augmenting and capital augmenting disembodied technical progress, respectively. Moreover, due to wear and tear, $I_{i,T}$ will decrease relative to $I_{T,T}$ in the course of time. This is expressed by:

$$I_{i,T} = \Omega_{i,-T} \cdot I_{T,T} \quad (4.5)$$

where $\Omega_{i,-T}$ represents the technical survival fraction of equipment of vintage $T$ in period $t$.

Expectations with Respect to Lifetime, Factor Prices and Output

As we mentioned above, the choice of a production technique is influenced by expectations with regard to lifetime, factor prices and output.

Expected lifetime is treated in different ways in putty–clay models. It can be considered as 'an endogenous variable intricately determined in the maximisation procedure in relation to, by all means, uncertain expectational values of wage rates, prices and discount rates'.

We share den Hartog's implicit reservations against this approach. In the face of so much uncertainty entrepreneurs are more apt to rely on simple rules of thumb. However, we think that it is too simple to assume that expected lifetime is constant throughout the whole estimation period, as for instance both KvZ and GWJ do. In fact, we do not agree with KvZ's statement that 'an expected lifetime is independent of the actual lifetime'. On the contrary, a plausible approach seems to us that expected lifetime is proportional to actual lifetime: KvZ found that actual lifetime decreased from 45 years in the early 1950s to 15 years in 1977, nonetheless they find an expected lifetime of 13 years throughout the whole period. We think that in the face of actual lifetime decreasing by two-thirds, expected lifetime must have decreased as well and therefore postulate:

$$P_t = \alpha \cdot L_t \quad \alpha \leq 1 \quad (4.6)$$

as a suitable approach to the entrepreneurial rule of thumb. $L_t$ stands for actual lifetime at year $t$.

With respect to expected prices and wages we follow common practice in assuming:

$$pe(t)_T = [1 + g^e(p)_T]^{-T} \cdot P_T$$

$$w^e(t)_T = [1 + g^e(w)_T]^{-T} \cdot w_T \quad (4.7)$$
where \( p^*(t)_T \) and \( w^*(t)_T \) represent expected prices and wages for year \( t \), with expectations formed in year \( T \), and \( g^*(p)_T \) and \( g^*(w)_T \) stand for the expected rates of growth of prices and wages, respectively. We assume that the expected rate of growth is equal to the average rate of growth over the past four years.\(^7\) Moreover, we make the same assumption with respect to the expected interest rate, i.e. \( r^*(t)_T \) is equal to the average interest rate over the past four years.

It is obvious that expectations with respect to capacity output of vintage \( T \) depend on expectations formed in year \( T \) with respect to aggregate demand for year \( t \), \( D^*(t)_T \). Essentially, these latter are formed in the same way as in the case of factor prices:

\[
D^*(t)_T = [1 + g^*(D)_T]^{t - T} \cdot D_T
\]  

(4.8)

where \( D_T \) stands for aggregate demand at year \( T \) and \( g^*(D)_T \) is the expected rate of growth of demand at year \( T \). Again we assume that the expected rate of growth is equal to the average rate of growth over the past four years.

We furthermore assume that investment behaviour of entrepreneurs is such that aggregate demand is met by employing equipment at a desired rate of utilisation, \( q^*_i \), which is smaller than unity.\(^5\) In this case desired aggregate capacity output in year \( t \) is:

\[
X^d(t)_T = D^*(t)_T \cdot q^*_i.
\]  

(4.9)

By definition desired capacity output of vintage \( T \), \( X^d_{T,T} \), should fill the gap between desired aggregate capacity output in year \( T \) and aggregate capacity output which can be produced by equipment still in existence at the end of year \( T - 1 \), \( X^-(T - 1) \).\(^6\) That is:

\[
X^d_{T,T} = X^d(t)_T - X^-(T - 1).
\]  

(4.10)

We assume that in the choice of the production technique entrepreneurs adjust productive capacity to desired capacity output with a factor \( \pi \), i.e.:

\[
X_{T,T} = \pi \cdot X^d_{T,T} \quad 0 < \pi \leq 1.
\]  

(4.11)

Essentially this implies that actual aggregate capacity output is a weighted average of desired capacity and capacity already existing at the end of the previous period.
The Choice of the Production Technique

Having specified the production structure ex post and expectations with respect to lifetime, factor prices and output, the choice of the production technique can be elaborated.

Substitution of equations (4.3), (4.4), (4.5) and (4.7) into equation (4.2) yields the expression for the present value of expected rent of equipment of vintage $T$ over its expected lifetime:

$$
\Phi = X_{t,T} \cdot p_t \cdot S_{t,T} - N_{t,T} \cdot w_t \cdot S_{t,T} - p_t' \cdot I_{t,T}
$$

(4.12)

with

$$
S_{t,T} = \sum_{i=1}^{I-1} \left\{ \frac{[1 + g'(p)_{T_i}] \cdot [1 + g'(h)_{T_i}] \cdot [1 + \gamma_t]^T}{[1 + r'(t)]} \right\} \cdot \Omega_{t,T}
$$

(4.13)

$$
S_{t,T} = \sum_{i=1}^{I-1} \left\{ \frac{[1 + g'(w)_{T_i}] \cdot [1 + g'(h)_{T_i}] \cdot [1 + \gamma_t]^T}{[1 + r'(t)] \cdot [1 + g'(h)_{T_i}] \cdot [1 + \gamma_n]} \right\} \cdot \Omega_{t,T}
$$

For a certain level of desired capacity output, $X_{t,T}$, maximisation of equation (4.12) with respect to labour, $N_{t,T}$, and investment, $I_{t,T}$, subject to equation (4.1) yields:

$$
\frac{N_{t,T}}{I_{t,T}} = \left( \frac{w_t \cdot S_{t,T}}{p_t'} \right)^{\alpha} \left[ A \cdot (1 + \mu_a)^T \cdot h_{nt} \right] \left[ B \cdot (1 + \mu_a)^T \cdot h_{nt} \right]^{-1}
$$

(4.14)

And the optimal levels of labour and investment corresponding to the desired level of capacity output can be derived from equations (4.1) and (4.14). This is illustrated in Figure 4.1, where $X_{t,T}$ determines the isoquant of the CES-production function (4.1), and, together with other variables, the ratio $w_t/p_t'$ determines the optimal labour intensity according to equation (4.14). We elaborate this later on.

Up to this point we discussed the investment decisions for each vintage as if they were taken by one single entrepreneur who has specific expectations with regard to future developments. However, by their very nature, entrepreneurs will have different expectations with respect to the future and for that reason they will take different investment decisions at a given moment of time. As a consequence, we cannot expect that a vintage is characterised by a single value of its labour intensity, as is the case in Figure 4.1. The labour intensity depicted in this figure should be interpreted as the average value of
the outcomes of different entrepreneurial decisions, whereas the individual outcomes are distributed around this average value. For analytical purposes we assume that entrepreneurial decisions differ in such a way that the amount of capital embodied in a unit of equipment varies uniformly on a range $I_b \cdots I_u$. If we furthermore approximate the isoquant segment $PQ$ using the line-segment $PQ,$ it follows that each point $I$ on the range $I_b \cdots I_u$ is associated with a point $N$ on the range $N_b \cdots N_u$, such that $N$ is uniformly distributed over the range $N_b \cdots N_u$; this is depicted in Figure 4.2. Since we assume that each unit of equipment can produce the same amount of output regardless of its capital intensity, it follows furthermore that the labour coefficients corresponding to different units of equipment vary uniformly on the range $N_b/X \cdots N_u/X$.

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**Figure 4.1** The determination of investment and demand for labour.

**Figure 4.2** The choice of equipment of vintage $T$. 

The values of capacity demand for labour and for investment can be found by integration of the uniform distributions over these ranges, i.e.:

\[
N_{T,T} = \frac{1}{N_u - N_b} \int_{N_b}^{N_u} N \cdot dN = \frac{1}{2} \cdot (N_b + N_u) 
\]
\[
I_{T,T} = \frac{1}{I_u - I_b} \int_{I_b}^{I_u} I \cdot dI = \frac{1}{2} \cdot (I_b + I_u).
\]

These values correspond to the values found in the analysis using Figure 4.1.\textsuperscript{14} Hence, the analysis of the production structure \textit{ex ante} does not change.\textsuperscript{15}

Nonetheless, the notion of a distribution in expectations can have far-reaching consequences compared with traditional vintage models. For in these models whole vintages are scrapped at a time, and this frequently gives rise to serious discontinuities in the model. Such discontinuities are implausible and can yield computational problems.\textsuperscript{16} In our model, however, these discontinuities are less pronounced. Moreover, as we shall demonstrate, the utilisation of equipment is treated in a far more plausible way.

\section*{Utilisation and Scrapping of Equipment}

An obvious scrapping condition, which is used in almost every vintage model, is negative quasi-rent - that is when, for equipment of a certain vintage:

\[
p_T \cdot X_{T,T} - w_T \cdot N_{T,T} < 0
\]

holds, the equipment becomes obsolete.\textsuperscript{17} However, it is also possible that equipment that is able to generate a positive quasi-rent is laid-off because of a slackening in aggregate demand. In that case aggregate demand is met by employing more efficient equipment. When the slackening in aggregate demand is persistent, the inefficient equipment will be scrapped because of underutilisation. GWJ also allow for scrapping because of excess capacity, although in a different way. When the three-year moving average of the rate of capacity utilisation is below the normal rate, a certain percentage of all vintages over two years of age is scrapped.\textsuperscript{18} However, we prefer to assume that equipment which is laid-off first is also scrapped first. As a consequence,
we assume that when the rate of capacity utilisation is below the normal rate for several consecutive years, a certain percentage of equipment which has been laid-off is scrapped in such a way that scrapping occurs to the least productive equipment.\textsuperscript{19}

Since we assume that labour productivity of equipment installed in a certain year varies over a certain range, equipment is not scrapped according to its year of installation as is usually assumed. This is illustrated in Figure 4.3 which shows equipment of different vintages (1-5) in increasing order of productivity. The range over which productivity varies for vintage $T$ at moment $t$ is indicated on the $X/N$-axis by the lowerbound $P_{l}(t, T)$ and the upperbound $P_{u}(t, T)$\textsuperscript{20} The size of the rectangle which represents vintage $T$ indicates the productive capacity corresponding to that vintage.\textsuperscript{21}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure43.png}
\caption{Distribution of vintages according to productivity.}
\end{figure}

When we indicate the fraction of productive capacity of vintage $T$ which has been scrapped for economic reasons in year $t$ by $1 - Q(t, T)$, we find that $Q(t, T)$ will lie between 0 and 1 for some vintages. In Figure 4.3 the real wage-rate, $w/p$, is indicated on the $X/N$-axis. It is clear that $Q(t, 5)$ is equal to 1 and $Q(t, 1)$ is equal to 0. However, equipment from vintages 2, 3 and 4 is only scrapped in so far as its productivity lies in the ranges $(P_{l}(t, 2), w/p)$, $(P_{l}(t, 3), w/p)$ and $(P_{l}(t, 4), w/p)$, respectively. Hence for these years $Q$ will lie between 0 and 1.
The discussion above implies that \( Q(t, T) \) is defined in the following way:\(^{22}\)

\[
Q(t, T) = \begin{cases} 
1 & P_n(t-1, T) > w_i / p_i \\
\frac{P_n(t-1) - 1}{\frac{w_i}{p_i} - 1} & P_n(t-1, T) < w_i / p_i < P_n(t-1, T) \\
\frac{P_n(t-1) - 1}{P_n(t-1)} & P_n(t-1, T) < w_i / p_i \\
0 & P_n(t-1, T) < w_i / p_i \end{cases}
\]

(4.18)

Since less productive equipment is scrapped first, the fraction of labour of vintage \( T \) which is scrapped for economic reasons, \( 1 - Q_n(t, T) \) will exceed that of output. The amount of labour which is not scrapped can be found by integration of \( N \) in equation (4.15) from \( N_n(t-1, T) \) to \( N^*(t, T) \), where:

\[
N^*(t, T) = N_n(t-1, T) + Q(t, T) \cdot (N_n(t-1, T) - N_n(t-1, T)).
\]

(4.19)

As a consequence we find:

\[
Q_n(t, T) = Q(t, T) \cdot Q^*_n(t, T)
\]

(4.20)

where

\[
Q^*_n(t, T) = Q(t, T) + [1 - Q(t, T)] \cdot \frac{2 \cdot N_n(t-1, T)}{N_n(t-1, T) + N_n(t-1, T)}.
\]

(4.21)

Obviously \( Q^*_n \) is smaller than 1, since \( N_n \) is smaller than \( N_n \). The resulting divergence between \( Q \) and \( Q_n \) is a consequence of the assumption that entrepreneurs will buy different equipment of a certain vintage.

For investment the opposite holds, since equipment that has lowest labour productivity in a certain vintage also has highest capital productivity. Denoting the fraction of investment of vintage \( T \) which is scrapped for economic reasons by \( 1 - Q_i(t, T) \), we find:

\[
Q_i(t, T) = Q(t, T) \cdot Q^*_i(t, T)
\]

(4.21)

where:

\[
Q^*_i(t, T) = Q(t, T) + [1 - Q(t, T)] \cdot \frac{2 \cdot I_i(t-1, T)}{I_i(t-1, T) + I_i(t-1, T)}.
\]
Obviously $Q^e$ exceeds 1, since $I_e$ exceeds $I_o$, and hence $Q_e$ exceeds $Q$.

As we mentioned above, vintages can also be scrapped because of persistent underutilisation. When the utilisation rate has been below its normal level for at least two consecutive years, least productive equipment will be scrapped until a percentage $\theta$ of excess capacity is scrapped. In the context of Figure 4.3 this would mean that all equipment for which labour productivity lies below $r$ but above $w/p$, is scrapped. Let the fraction of profitable capacity of vintage $T$ which is scrapped in year $t$ because of underutilisation be $1 - R(t, T)$. In the same way $1 - R_a(t, T)$ and $1 - R_i(t, T)$ refer to labour and investment, respectively. Then it is obvious that $R, R_a$ and $R_i$ are defined analogously to $Q, Q_a$ and $Q_i$. That is:

$$R(t, T) = \begin{cases} 1 & P_a(t-1, T) > r, \\ \frac{P_a(t-1, T)}{Q(t, T)} & P_a(t-1, T)/P_b(t-1, T) < 1, \\ 0 & P_a(t-1, T) < r. \end{cases}$$

(4.22)

and

$$R_a(t, T) = R(t \cdot T) \cdot R_a^e(t, T)$$

(4.23)

where:

$$R_a^e(t, T) = R(t, T) + [1 - R(t, T)] \cdot \frac{2 \cdot N_a(t-1, T)}{N_a(t, T) + N_b(t-1, T)}.$$  

(4.24)

and

$$R_i(t, T) = R(t, T) \cdot R_i^e(t, T)$$

where:

$$R_i^e(t, T) = R(t, T) + [1 - R(t, T)] \cdot \frac{2 \cdot I_a(t-1, T)}{I_a(t-1, T) + I_b(t, T)}.$$  

(4.24)

In equations (4.18)–(4.24) we use the boundary values of the previous period. The reason is that we refer to equipment which has survived scrapping in the previous period. Finally, as a consequence of this scrapping, the upper boundary of labour and the lower boundary of investment will change. Moreover, both boundaries of labour will change because of disembodied technical progress and changes in
working-time.\(^{25}\) Therefore we find:

\[ I_u(t, T) = I_u(t-1, T) \]

\[ I_u(t, T) = I_u(t-1, T) - R(t, T) \cdot Q(t, T) \]

\[ \cdot (I_u(t-1, T) - I_b(t-1, T)) \]

\[ N_b(t, T) = N_b(t-1, T) \cdot \frac{1 + \gamma_i}{1 + \gamma_n} \cdot \frac{h_i}{h_{i-1}}/\frac{h_{i-1}}{h_{i-1}} \]

\[ N_u(t, T) = N_u^*(t-1, T) \cdot \frac{1 + \gamma_i}{1 + \gamma_n} \cdot \frac{h_i}{h_{i-1}}/\frac{h_{i-1}}{h_{i-1}} \]

\[ N_u^*(t, T) = N_u^*(t-1, T) + R(t, T) \cdot Q(t, T) \cdot (N_u(t-1, T) - N_b(t-1, T)) \]

When we take into account both the influence of variation in entrepreneurial expectations and the influence of scrapping, equations (4.3)–(4.5) should be replaced by:\(^{26}\)

\[ I(t, T) = I(t-1, T) \cdot \Omega_i/T/\Omega_{i-1,T} \cdot R(t, T) \cdot Q_i(t, T) \]

\[ X(t, T) = X(t-1, T) \cdot (1 + \gamma_i) \cdot \frac{h_i}{h_{i-1}} \cdot \frac{1}{Q_i^*(t, T) \cdot R_i^*(t, T)} \]

\[ X(t, T) = X(t-1, T) \cdot (1 + \gamma_n) \cdot \frac{h_i}{h_{i-1}} \cdot \frac{1}{Q_i^*(t, T) \cdot R_i^*(t, T)} \]

These equations differ from equations (4.3)–(4.5) due to the presence of the various factors \( Q \) and \( R \), which is not remarkable since these factors reflect differences in entrepreneurial expectations and scrapping due to economic obsolescence and underutilisation.

**Aggregation and Hoarding of Labour**

It is obvious that capacity output and demand for labour, \( X_t^c \) and \( N_t^c \), respectively, are defined by:

\[ X_t^c = \sum_{T \in V_{(t)}} X_{t,r} \]

\[ N_t^c = \sum_{T \in V_{(t)}} N_{t,r} \] (4.29)
\[ V(r) \text{ is the set of vintages consisting of equipment which labour productivity is at least equal to } r. \text{ If } X_i^q > X_i^r, \text{ then we define the value } Q' \text{ for labour productivity such that:} \]

\[ \sum_{\tau \in V(Q')} X_{i\tau} = X_i \quad \text{(4.30)} \]

holds. This enables us to define the amount of labour which would have been exactly sufficient to produce actual demand \( X_i \), as:

\[ N_i' = \sum_{\tau \in V(Q')} N_{i\tau}. \quad \text{(4.31)} \]

Idle labour, \( N_i' \), is then equal to:

\[ N_i' = N_i'^{-} - N_i'^{+}. \quad \text{(4.32)} \]

We assume that there are two types of labour hoarding, i.e. desired hoarding and forced hoarding. The first type of labour hoarding may be regarded as a tactical reserve of idle labour which may be activated at any time, while the second type of labour hoarding is caused by institutional factors which inhibit an instantaneous adjustment of the demand for labour to its optimum level. Actual labour hoarding is equal to the maximum of both types of hoarding. Assuming that desired hoarding is equal to a fraction \( \zeta_1 \) of idle labour, and furthermore assuming that forced hoarding equals a fraction \( \zeta_2 \) of actual labour hoarding in the previous period, it follows that demand for labour is equal to:

\[ N = N' + \max (\zeta_1 \cdot (N^r - N'), \zeta_2 \cdot (N_{-1} - N_{-1}')) \quad \text{(4.33)} \]

**Investment**

From the discussion of Figure 4.1 one can conclude that both investment and capacity demand for labour are endogenous in the model. In this paragraph we will concentrate on investment only, however, since capacity labour demand associated with new investment follows directly both from the amount of investment and the optimal labour intensity of new investment (cf. equation [4.14]).

From equations (4.1) and (4.14) the following investment function can be derived:

\[ I_{i\tau} = X_{i\tau} \cdot \left[ A' \cdot \Psi^{(\sigma-1)/\sigma} + B' \right]^{\sigma/(1-\sigma)} \quad \text{(4.34)} \]
where
\[ A' = (A \cdot (1 + \mu_a)^{T} \cdot h_n T)^{(\alpha - 1)/\sigma} \]
\[ B' = (B \cdot (1 + \mu_d)^{T} \cdot h_T)^{(\alpha - 1)/\sigma} \]
\[ \Psi = \left( \frac{B' \cdot w_T \cdot S_{n, T}}{A' \cdot p_T} \right)^{-\alpha} \]
(cf. equation [4.14])

The first argument in equation (4.34) represents the influence of expected demand on investment and the second argument represents the influence of expected factor-price developments. Both expected demand and the ratio of expected wages to the price of investment exert a positive influence on investment.

However, one should recall from equation (4.10) that \( X_{T,T} \) does not only represent expected demand, but also aggregate capacity output which can be produced by equipment installed at the end of year \( T - 1 \), \( X^-(T - 1) \). From equation (4.29) it can be seen that \( X^-(t - 1) \) is defined as follows:

\[ X^-(t - 1) = \sum_{T \in V(r, t)} X_{T,T} \quad (4.35) \]

where \( V(r, t) \) is the set of vintages older than \( t \) with equipment which labour productivity is at least equal to \( r \). Hence, factor-price developments also influence investment via \( X_{T,T} = \pi \cdot [X^d(T) - X^-(T - 1)] \), because \( V(r, t) \) is influenced by factor prices. This will increase the negative impact on employment of a relative wage increase.

Investment is also influenced by unutilised capacity, even in two different ways. First, persistent excess capacity will lead to scrapping of equipment. As a consequence the capital stock and hence \( X^-(T - 1) \) will decrease. This has a positive influence on investment, given desired aggregate capacity output. However, both components of this latter variable – expected demand and the desired rate of utilisation – will probably be influenced by persistent excess capacity. Excess capacity indicates that in the past too high a demand has been expected. Hence, future expected demand will be negatively influenced by excess capacity. The influence on the rate of capacity utilisation is not clear, however, because persistent excess capacity will not decrease the desired rate of utilisation when it is already so low as to allow for this excess capacity. On the whole we expect that the negative influence of excess capacity on investment dominates the positive influence because of its impact on expected demand.
Employment, Unemployment and Labour Hoarding

As we stated in the introduction, one of our motivations for developing the putty-clay model is to analyse unemployment. However, up to now we have only explained actual demand for labour, whereas an analysis of unemployment requires an explanation of employment. Hence, the relation between actual demand for labour and employment has to be elaborated. For this purpose we use the concept of an employment function which relates employment in year $t$, $E_t$, to demand for labour, $N'_t$, and supply of labour, $N'_t$. In general this function can be defined as:

$$E_t = F(N_t, N'_t)$$ (4.36)

It is assumed to be linearly homogeneous in both arguments. We follow Muysken (1987) in the use of this function to distinguish between qualitative and quantitative structural unemployment on the one hand and cyclical unemployment on the other. Qualitative structural unemployment, $U'_t$, results from qualitative discrepancies between supply of and demand for labour. Usually it is measured by the amount of unemployment where unemployment and vacancies are equal, and hence $E_t = N'_t \cdot F(1,1)$ holds. As a consequence we find:

$$U'_t = N'_t\{1 - F(1, 1)\}$$ (4.37)

Quantitative structural unemployment, $U'_t$, is the unemployment that results, apart from qualitative structural unemployment, when all equipment is used at normal capacity. Employment is then given by:

$$E'_t = F(q^{n^*_t} \cdot N'_t, N'_t)$$

and:

$$U'_t = N'_t\{F(1, 1) - F(q^{n^*_t} \cdot N'_t/N'_t, 1)\}$$ (4.38)

holds. $q^{n^*_t}$ equals the normal rate of utilisation of labour ($q^{n^*_t} = N'_t/N'_t$, where $N'_t$ is equal to the amount of labour associated with the most productive equipment which would have been used to produce an amount of output exactly equal to $q^*_t \cdot X_{*,t}$). Obviously, quantitative structural unemployment is due to a shortage of capacity demand for labour.
Finally, the remaining unemployment, \( U_i' \), is of a cyclical nature, and can be written as follows:

\[
U_i' = N_i' \cdot \{ F(q_{ni}^\text{e} N_i'/N_i', 1) - F(q_{ni} \cdot N_i'/N_i', 1) \} \tag{4.39}
\]

where \( q_{ni} \) is the rate of utilisation of labour. Equation (4.39) shows that cyclical unemployment varies inversely with the rate of utilisation of labour. Furthermore, since most productive equipment is used first, it follows that, \textit{ceteris paribus}, a rise in the rate of capacity utilisation generates a more than proportional rise in the rate of labour utilisation. Therefore cyclical changes in unemployment tend to be more outspoken than changes in the rate of capacity utilisation itself.

4.3 THE ESTIMATION OF THE MODEL

We have estimated the model for the period 1960–82, and in order to check the reliability of the estimation results, we forecast for the years 1983–4. Although investment is endogenous in our model, we treat it as exogenous in the estimation process in order to keep this process manageable. However, we feel that the estimation results with exogenous investment are already interesting enough to be presented in more detail. Before presenting the estimation results, we will first discuss the data and the estimation method used.

The Data and the Estimation Method

For the period 1905–84 data for value added excluding natural gas and housing, investment in equipment and means of transportation, wages, prices of investment and of value added, and the long-term interest rate were obtained from GWJ upon request. Moreover, for the period 1947–84 data were obtained from the same source on employment, vacancies and the rate of capacity utilisation. With respect to technical scrapping the assumptions from den Hartog and Tjan (1980) have been followed. Finally we do not distinguish between working hours for equipment and personnel, but use the same data for both, as KvZ do.

With respect to the estimation procedure it seems sensible to define the objective function in terms of the two strategic variables of the model: capacity output and actual demand for labour. Capacity output is defined as actual output divided by the rate of capacity
utilisation, and demand for labour is defined as employment plus vacancies. The estimation procedure should minimise the following objective function:\[ F = \sum_{r=1960}^{1962} (X''_r/X'_r - 1)^2 + (N''_r/N_r - 1)^2 \] (4.40)

where $X'_r$ and $N_r$ are observed capacity output and actual demand for labour, respectively, and $''$ denotes computed values. The objective function is minimised by means of a non-linear search procedure over all parameters to be estimated. For this purpose we used a quasi-Newton algorithm (E04JBF from the NAG library).

The Estimation Results

Before presenting the estimation results, some comments should be made on the role of technical progress. The computed values of capacity output and demand for labour appear to be very sensitive to changes in the rate of technical progress. Hence the specification of technical progress is important. From that point of view efforts to endogenise technical progress may be considered to be very useful. However, there is no strong tradition in this field and thus far only modest results have been obtained with endogenous technical progress in empirical models. It should therefore not be too surprising that we have not been able to find a specification for technical progress that is satisfactory from both a theoretical and an empirical point of view.\[36\]

From our estimation results, though, it was clear that the assumption of a constant rate of technical progress during the entire estimation period could be held responsible for some misfits, in particular in the periods 1964–71 and 1975–81. As a consequence we introduced dummy-variables for the rate of technical progress in these two sub-periods.\[39\] Furthermore, we followed the tradition of setting the rate of embodied labour augmenting technological progress before 1948 at a constant fraction of its post-war value.\[40\]

The fits of the computed values of the rate of capacity utilisation and demand for labour to their observed counterparts are presented in Figures 4.4 and 4.5, respectively. From these figures it can be seen that the model fits the data well.\[41\] Moreover, when we extrapolate the model for the years 1983–4, it turns out that the predicted value of the rate of capacity utilisation reverses its downward trend to an upward trend as is the case with its actual value, although the turning-
point is predicted one period late. Moreover, the actual value is slightly underestimated – by 1.5 percentage points in 1984. The reverse in the downward trend of demand for labour is also predicted quite well, but actual demand for labour is overestimated – by about 128 thousand man-years in 1984. We will comment on that later.

The estimation results for the parameter values are presented in Table 4.1. Those results which are comparable with the results found
### Table 4.1 The parameter estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>11.5810</td>
<td>B,</td>
<td>2.2518</td>
</tr>
<tr>
<td>σ</td>
<td>0.3759</td>
<td>μ^1</td>
<td>0.0477</td>
</tr>
<tr>
<td>μ^1</td>
<td>0.0539</td>
<td>μ^0</td>
<td>0.0051</td>
</tr>
<tr>
<td>μ^0</td>
<td>0.0113</td>
<td>γ^0</td>
<td>0.0040</td>
</tr>
<tr>
<td>γ^0</td>
<td>0.0000</td>
<td>γ^1</td>
<td>0.0000</td>
</tr>
<tr>
<td>γ^1</td>
<td>0.0125</td>
<td>γ^1*</td>
<td>0.0000</td>
</tr>
<tr>
<td>γ^1*</td>
<td>0.0000</td>
<td>θ</td>
<td>0.6950</td>
</tr>
<tr>
<td>μ^0*</td>
<td>0.1926</td>
<td>θ</td>
<td>0.4579</td>
</tr>
<tr>
<td>sp,^*</td>
<td>2.0000</td>
<td>i-range^d</td>
<td>0.2828</td>
</tr>
<tr>
<td>ε^1</td>
<td>0.5178</td>
<td>ε^2</td>
<td>0.3921</td>
</tr>
<tr>
<td>F^*</td>
<td>0.0066</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

a. **fixed on a priori grounds**

b. multiplication factor of embodied labour-augmenting technical progress, i.e.

\[
\mu_{u}^{1} = \mu_{o} \cdot \mu_{u}^{1*}
\]

where " denotes the value of embodied labour-augmenting technical progress from 1948 onwards, and ' denotes its pre-1948 equivalent.

c. lag with respect to scrapping on account of underutilisation, i.e. if the (initial) rate of capacity utilisation is smaller than the normal rate of capacity utilisation for a period of sp years, then part of excess capacity is scrapped.

d. the amount of capital varies uniformly over a range \( i' + / -0.145 \cdot \ell \), where \( \ell \) is the average amount of capital embodied in a certain vintage.

e. value of objective function.

in KvZ and GWJ are also presented in Table 4.2, together with alternative estimates.

With respect to the parameters describing the production structure, the elasticity of substitution and the nature and rate of technical progress should be considered as the most interesting one estimated value of the elasticity of substitution is 0.38, which is close to the values found by KvZ and GWJ. However, with respect to technical progress we find somewhat different results.

Taking embodied and disembodied labour-augmenting technical progress together, we find approximately the same results – al
Table 4.2 Estimation results compared with KvZ and GWJ

<table>
<thead>
<tr>
<th></th>
<th>KvZ</th>
<th>GWJ</th>
<th>MuZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>estimation period</td>
<td>1950-77</td>
<td>1960-82</td>
<td>1960-82</td>
</tr>
<tr>
<td>elasticity of substitution</td>
<td>0.32</td>
<td>0.44</td>
<td>0.38</td>
</tr>
<tr>
<td>embodied technical progress (%)</td>
<td>4.75</td>
<td>2 – 3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.77 &lt;sup&gt;b&lt;/sup&gt;(5.38, 0.50)</td>
</tr>
<tr>
<td>labour-augmenting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fraction in pre-war period&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.25</td>
<td>0.1 – 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.195</td>
</tr>
<tr>
<td>capital augmenting</td>
<td>0</td>
<td>0</td>
<td>1.13</td>
</tr>
<tr>
<td>disembodied technical progress (%)</td>
<td>0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2 – 3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.40 &lt;sup&gt;e&lt;/sup&gt;(0, 0)</td>
</tr>
<tr>
<td>labour-augmenting</td>
<td>0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0</td>
<td>1.25 &lt;sup&gt;b&lt;/sup&gt;(0, 0)</td>
</tr>
<tr>
<td>capital-augmenting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>expected lifetime (years)</td>
<td>13</td>
<td>15</td>
<td>25 – 8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes
<sup>a</sup> approximate range of variation of endogenous technical progress in the post-war period;
<sup>b</sup> values for the periods 1964–71 and 1975–81, respectively;
<sup>c</sup> fraction of the post-war rate of labour-augmenting embodied technical progress;
<sup>d</sup> for the 1950s a value of −1.75 per cent is found;
<sup>e</sup> a fraction 0.7 of actual lifetime. Actual lifetime decreases from 45 years in 1960 to 12 years in 1982. See also note 42.

per cent – as both KvZ and GWJ do – except for the late 1970s where we find technical progress to be almost absent. But while GWJ find similar magnitudes for both embodied and disembodied technical progress, we find labour-augmenting technical progress to be almost totally embodied, which is also the case in KvZ. On the other hand, neither KvZ nor GWJ find any capital-augmenting technical progress, whereas we find rates of technical progress, both embodied and disembodied, of over 1 per cent. One should realise, however, that according to our results there is no disembodied capital-augmenting technical progress in the late 1960s or the late 1970s. As a consequence of these differences, we find that, compared with our results, both KvZ and GWJ slightly overestimate the labour intensity of new equipment. But they also overestimate the rate of decrease over time of the labour intensity of equipment installed, which partly compensates the previous overestimation.
With respect to the parameters describing entrepreneurial behaviour, we distinguish between the choice of the production technique, scrapping and labour hoarding. With regard to the choice of the production technique we find that expected lifetime of equipment is a fraction 0.7 of actual lifetime. As a consequence, expected lifetime decreases from 25 years to 8 years in the estimation period, compared with a fixed number of 13 and 15 years estimated by KvZ and GWJ, respectively.\textsuperscript{42}

We also find that entrepreneurial behaviour differs such that the labour intensity of new equipment is distributed over an interval of 29 per cent around its average value. In 1950 the labour intensity chosen varied in the range 5.83–8.33 and in 1984 in the range 2.40–3.46. This is quite considerable, hence differences in entrepreneurial behaviour should not be ignored. The importance of differences in entrepreneurial behaviour can also be seen in Figure 4.6 where the upper and lower boundaries of labour productivity of new equipment are presented. From that figure one sees that a certain level of labour productivity can be found in equipment of several vintages, in particular in the late 1970s. Hence, when the wage-rate corresponds to that level of labour productivity, equipment of several vintages will be scrapped. For instance, from Figure 4.6 it can be seen that in the period 1973–81 new equipment was installed with labour productivity

\textit{Figure 4.6} Labour productivity - boundaries of new equipment

![Figure 4.6: Labour productivity - boundaries of new equipment](image-url)
ranges which were virtually the same. So, when at some moment of
time the real wage rate lies within these productivity ranges, it follows
that all these vintages will be partially scrapped at the same time.\textsuperscript{43}

With respect to scrapping behaviour, the parameters to be estimated
concern scrapping as the result of excess capacity. We find that when
the rate of capacity utilisation is below its normal level of 98 per cent
for two consecutive years, a fraction 0.46 of least productive equipment
that has been laid-off is scrapped. In Figure 4.7 we show equipment
scrapped for various reasons as a percentage of total production
capacity. A more or less constant proportion of 2 to 3 per cent over
the estimation period is scrapped because of technical obsolescence.

\textit{Figure 4.7} Percentage of production capacity scrapped for technical, tech-
nical plus economic, and technical, economic and underutilisation reasons.

An additional 5–7 per cent is scrapped because of negative quasi-rent
in the years 1965–79. In the early 1960s and from 1976 on equipment
was scrapped because of underutilisation. In particular from 1980
onwards, this scrapping because of excess capacity is high, varying
between 8 and 10 per cent. This reflects the sharp decline in the rate
of capacity utilisation. Finally, one should realise that scrapping
because of underutilisation occurs to the least productive equipment.
Therefore this is often accompanied by a zero rate of scrapping because of negative quasi-rent in subsequent periods.\textsuperscript{44}

The parameters to be estimated with regard to labour hoarding concern the fraction of idle labour to be hoarded, which is estimated to be 52 per cent, and the fraction of labour hoarded in the previous period which cannot be discarded, which turns out to be 38 per cent. Actually, it turns out that labour hoarding in the previous period led to involuntary labour hoarding in the subsequent period in only a few years.\textsuperscript{45} Hence, in most years demand for labour is described by:

\[ N_i = N_i' + 0.52(N_i^* - N_i') \]  \hspace{1cm} (4.41)

where \( N_i' \) stands for labour necessary to produce current output, employing the most efficient equipment.

The development of labour hoarding, \( N_i - N_i' \), can be seen in Figure 4.8, where data are presented on \( N_i^* \), \( N_i \), and \( N_i' \). Labour hoarding is estimated as high in the early 1960s, with a peak of 159 thousand man-years in 1963, and then low till the mid-1970s. In 1975 it jumped to a level of 157 thousand man-years and then increased to about 300 thousand in 1982-4.

One should realise that our results with respect to demand for labour differ markedly from the ones of KvZ and GWJ, for they find that

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.8.png}
\caption{Figure 4.8}
\end{figure}
past employment or demand for labour influence current employment or demand for labour strongly, by a factor of proportion of 0.8 and 0.75, respectively. The motivation of their specifications is that hoarding in the previous period is carried over to the present period. Our results, though, indicate that this kind of hoarding is not very relevant for the period under study.

Equation (4.41) can also be used to explain the error in the prediction of the demand for labour, which can be seen in Figure 4.5. From Figure 4.4 one can see that the rate of capacity utilisation is estimated to be 87.7 per cent instead of 89.2 per cent in 1984. Hence capacity output should be estimated to be 1.7 per cent lower and as a consequence capacity demand for labour should be estimated at least 1.7 per cent lower. However, according to equation (4.41) capacity demand for labour should be about 6 per cent lower, provided that \( N_t \) does not change, in order to eliminate the prediction error in actual demand for labour. A possible reason for the prediction errors in both capacity output and capacity demand for labour then is that disembodied capital-augmenting technical progress has been overestimated after 1981 and that disembodied labour augmenting technical progress has been underestimated. But instead of trying to solve this by means of the introduction of another dummy variable for the rate of technical progress, this should be regarded as an additional stimulus to look for a satisfactory way to endogenise technical progress.

Cyclical and Structural Unemployment

As we explained earlier, the estimation results can be used to decompose unemployment in its cyclical and structural components, according to equations (4.37)–(4.39). For the employment function we used the function that has been derived in Kooiman and Kloek (1979) and which is used in the FREIA-model. The results are presented in Figure 4.9.

From the figure one sees that qualitative structural unemployment grew from about 70 thousand man–years in 1960 to about 120 thousand man–years in 1984. Quantitative structural unemployment was negative during the first half of the 1960s, reaching its lowest value of −53 thousand man–years in 1964. Then it climbed, slowly at first, to a level of 354 thousand man–years in 1984. This result is in line with the conclusion found in many vintage models for the Netherlands that the 1960s were characterised by labour shortage while the 1970s and early 1980s were characterised by capital shortage. But there is one
important difference. Most models explain capital shortage by a high real wage-rate which induces scrapping due to economic obsolescence. As can be seen from Figure 4.7 this is consistent with the present model for the situation in the early and mid-1970s. But it can also be seen from this figure that in the late 1970s and early 1980s capital shortage was caused by a persistent low rate of capacity utilisation which led to scrapping due to underutilisation. Hence, the cause of quantitative structural unemployment has changed from a high wage-rate to a low rate of capacity utilisation.

Cyclical unemployment was low in the 1960s and the first half of the 1970s. Its cyclical movements follow the business cycle of the economy which can be inferred from the time-series of the rate of capacity utilisation, presented in Figure 4.4. Booms appear in 1960, 1971 and 1976. Moreover, the rise in cyclical unemployment from a level of 67 thousand man-years in 1976 to 190 thousand man-years in 1983 mirrors the decrease in the rate of capacity utilisation during that period.

With respect to the nature of unemployment we conclude that the rise in unemployment from 325 thousand man-years in 1980 to 800 thousand man-years in 1983 and 1984 is explained both by a deterioration of the cyclical situation and an insufficient level of capacity demand for labour relative to labour supply. The latter was
caused by the low level of capacity utilisation which led to scrapping of equipment (due to idleness) to about 10 per cent of productive capacity, as can be seen from Figure 4.7.

4.4 CONCLUSIONS

The analysis presented in this paper contains some theoretical innovations with respect to earlier putty-clay vintage models. As a consequence the development of employment and unemployment in the Netherlands is explained in a different way from models like KvZ and GWJ. This applies in particular to the development of unemployment in the last decade.

The main theoretical innovations in our putty-clay vintage model are the consistent use of the notion of efficient utilisation of equipment and the assumptions that a range of labour intensities of a certain vintages is chosen of which the distribution is known. Moreover, the model is complemented with an employment function, which enables us to integrate the various components of unemployment in a coherent way in our model. The assumptions of a distribution of labour intensities, together with an efficient utilisation of equipment are very useful; for instance, hoarding of labour can be studied explicitly.

An interesting empirical finding in this context is that hoarding in a certain period has less spillover to the next period than is usually assumed. Another interesting empirical finding is that in the late 1970s and early 1980s scrapping due to excess capacity turns out to have been relevant. As a consequence of it, the low level of the rate of capacity utilisation not only caused a high level of cyclical unemployment, but due to the persistence of its low level, it also caused a high level of quantitative structural unemployment. Therefore the latter was no longer caused by a high wage-rate, as was the case in the early and mid-1970s.

Although our model does fit the data well and yields plausible results, several questions still remain to be answered. An important conclusion of our empirical analysis is that technological change should no longer be considered as a constant rate of change. This implies that an explanation of the rate of technological change is required. It remains to be seen whether such an explanation will provide a better prediction for the years 1983–4 of demand for labour and the rate of capacity utilisation. But whatever these results are, we think that the explanation of demand for labour could be improved
anyway, by incorporating the notion of labour hoarding in the analysis of aggregation by integration which underlies the employment function. Finally, an obvious shortcoming of our empirical analysis is that we treated investment as exogenous.

We think that our analysis has provided not only interesting questions for further research, but also indicated new directions for such research. This holds in particular for the notion of efficient utilisation of equipment in combination with the insight that entrepreneurial behaviour, by its very nature, leads to a spectrum of choices which are realised at a certain moment of time, and which outcomes are distributed in a certain way. These insights have already been proved to be worthwhile in the present analysis.

Notes

3. We treat it as exogenous in the estimation process, however, in order to keep this process manageable.
4. These variables are defined at maximum-capacity utilisation, where the utilisation rate is equal to 1.
7. In Kuipers and van Zon (1982) this period is a parameter to be estimated, they find as a result four years (p. 51). Gelauw et al., p. 337, assume this period to be ten years, which seems rather long to us.
8. Both Kuipers and van Zon and Gelauw et al. assume a normal rate of capacity utilisation which is constant during the entire estimation period, cf. Kuipers and van Zon (1982) p. 48, where $q^N = 1$ and the rate of capacity utilisation is allowed to exceed 1, and Gelauw et al., p. 337 where $q^N = 0.98$ and $q$ cannot exceed 1. Like Gelauw et al., we have taken $q^N$ to be equal to 0.98. We have, however, experimented with a variable normal rate of capacity utilisation which is equal to the average rate of capacity utilisation over the past eight years. The outcomes were virtually the same as the ones obtained using a fixed normal rate of capacity utilisation. This is not too surprising however, since on the one hand the actual rate of capacity utilisation lies below the normal rate of capacity utilisation in the late 1970s and early 1980s in both cases. On the other hand the rate of scrapping due to underutilisation is not related to the degree of underutilisation. See also note 19.
9. $X'(T - 1)$ is defined in equation (4.35).
10. This function is similar to Kuipers and van Zon, equation (2.12). We treat expectations with regard to $h_l$ and $h_u$ analogously to those with regard to $r$. 
11. This notion is inspired by the distribution approach to the aggregation of production functions; cf. Johansen (1972), Sato (1975) and Muysken (1987).

12. Otherwise the CES-function should be included in the integrand.

13. The values of $N_b$ and $N_a$ can be derived in a straightforward manner by substitution of $I_{bT}$ and $I_{aT}$ in equation (4.1). For instance:

$$N_{bT} = \left(\frac{(X_{T,T})^{-\eta} - B(1 + \mu_a)^{1/T} - I_{aT})^{-\eta}}{A \cdot (1 + \mu_a)^{1/T} - I_{bT})^{-\eta}}\right)^{-1/\eta}$$

14. Actually, these values hold only approximately, because of the linear approximation of the isocost segment $PQ$. We correct for this approximation error by rescaling $N_b$ and $N_a$ such that $(N_b + N_a)/2 = N_{bT}$ holds exactly. For instance, the lower bound becomes $N_b = N_{bT} - (N_a - N_b)/2$.

15. However, now we can explain why investment takes place at the same time that equipment is scrapped due to underutilisation: Successful and unsuccessful entrepreneurs coexist and while the unsuccessful entrepreneurs scrap their equipment, the successful ones expand.


17. However, we assume that when labour productivity is compared with the real wage rate, entrepreneurs do not consider the real wage rate of that year, but the average real wage rate of the past two years and the current year. Compare Kuipers and van Zon, p. 18 and Gelauff et al., p. 334, who do the same.


19. A possible future extension of the model is the assumption of a variable proportion of excess capacity to be scrapped, for it seems likely that in times of severe underutilisation a larger proportion of excess capacity will be scrapped than in times of a relatively small amount of excess capacity.

20. $P_b(t, T) = X(t, T)/N_b(t, T)$ and $P_a(t, T) = X(t, T)/N_a(t, T)$. We discuss the time-indices of these boundaries later. For the purpose of calculating the labour productivity boundaries, $X(t, T)$, $N_b(t, T)$ and $N_a(t, T)$ are evaluated exclusive of the influence of technical decay. See also note 25.


22. One should realise that $N/X$ is distributed uniformly over the range $(1/P_b(t, T), 1/P_a(t, T))$.

23. Hence $r$ is determined such that aggregate productive capacity of all equipment for which $r > X/N > w/p$ is equal to the amount of productive capacity to be scrapped.

24. $I^*(t, T) = I(t - 1, T) - Q(t, T) \cdot (I(t - 1, T) - I(t - 1, T))$.

25. Scrapping due to technical obsolescence will not affect the boundaries because this occurs to all equipment of a certain vintage simultaneously.

26. These equations are similar to equations (2.23)–(2.25) of Gelauff et al., except for the presence of the factors $Q_1$, $Q_2$, $R_1^1$ and $R_2^2$. Since
Gelauff et al. do not allow for different expectations, they assume these factors to be equal to 1.

Equation (4.34) refers to the average amount of capital embodied in equipment of vintage $T$. We assume that expectations among entrepreneurs differ such that aggregation over the different types of equipment yields the average values of $I$ and $N$.

For an extensive discussion of this function we refer to Muysken (1986) pp. 5–7.


We ignored the development in the 1950s which are notoriously difficult to describe. See for instance the results of Kuipers and van Zon (1982) for this period.

Incorporation of investment in the analysis would increase the number of parameters to be estimated simultaneously and would probably require a refinement of the assumptions underlying the modelling of investment behaviour. We consider this as a matter of future research.

Gelauff et al. refer to the data used by the Central Planning Bureau for the Dutch annual model FREIA (CPB, 1983).

With respect to the rate of capacity utilisation one should note that the data used by Gelauff et al. in their publication differ from those published by the Central Bureau of Statistics, in particular from 1980 on. For that reason we extrapolated these data for the period 1983–4 using the CBS-data.

i.e. we used the same technical survival scheme ($\Omega$) and we assume that war damage on vintages installed before 1946 is 40 per cent — these assumptions are common in most Dutch empirical vintage models.


When investment is endogenous this would be the third strategic variable.

A penalty is given when the estimated value of $N^*$ drops below 99 per cent of actual demand for labour, $N$.

Gelauff et al. (1985) pp. 331–2, assume that, apart from an autonomous component, embodied technical progress depends on the structural rate of change in the export share, whereas disembodied technical progress depends on the sum of the rates of growth of exports and national product. These particular functional specifications are hardly justified, however. Efforts to include the influence of relative factor-prices failed either because of identification problems (embodied) or because of poor empirical results (disembodied).

An exception is made for the rate of embodied capital augmenting technical progress, for which the model appeared to be less sensitive.

This tradition is initiated by den Hartog and Tjan (1974), who use a fraction of 0.25, motivated on a priori grounds.

These results are better than those of Gelauff et al.: in particular with respect to the fit of the rate of capacity utilisation. This can be seen when we compare our Figure 4.4 with their Figure 3.1. Gelauff et al. underestimate the rate of capacity utilisation during the period 1960–9
and overestimate it in the period 1973-8, while our estimate does not show such systematic errors.

42. We have imposed an upper limit on expected lifetime of 25 years.
43. We ignore the influence of disembodied technical progress, which is low.
44. This explains one difference from the results presented by Gelauff et al. in their Figure 3.5. Part of the difference between our results and the ones of Gelauff et al. is caused by the fact that we have defined scrapping in terms of productive capacity rather than in terms of the capital stock, as Gelauff et al. have done. Because of disembodied technical progress, capital productivity increases over time. Therefore, in our case, old vintages may be more important from a scrapping point of view than is the case with Gelauff et al. which only consider the amount of capital embodied in those vintages. In addition to this, the (relative) amount of capital scrapped because of underutilisation is effectively bounded from above to about 4 per cent in the case of Gelauff et al. (see Gelauff et al., 1985, pp. 334-5) while such an upper limit does not exist in our case. But apart from these differences, the results are quite comparable.

45. These are the years 1965, 1970, 1971 and 1976.
47. It turns out that when disembodied capital-augmenting technical progress remains zero, as it was till 1982, and disembodied labour-augmenting technical progress is increased to a level of 1.65 per cent, both the computed rate of capacity utilisation and computed demand for labour fit the observed values in 1982-4 very well.
48. CPB (1983) p. 23; we also used the parameter values presented in that publication, since the model was estimated for approximately the same period. One drawback of this particular specification is that the friction parameter has been estimated with a linear time-trend. As a consequence, qualitative structural unemployment is a percentage of the labour force grows along a linear time-path.
50. Note, however, that because of the overestimation of labour demand in 1983 and 1984, unemployment is underestimated in those years.

References


