VACANCIES AND MOBILITY ON THE HOUSING MARKET; AN EXPLORATORY ANALYSIS FOR THE NETHERLANDS

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Research memorandum 1982-22 September '82
1. Introduction

In many countries the housing market is characterized by disequilibria. These disequilibria relate among others to the fact that the housing stock is given in the short run while the demand for housing may change considerably in a relatively short period. Fluctuations in housing demand may be due to factors such as changes in income, demographic changes, changes in household formation and tendencies to migrate to specific regions. Another source of disequilibria may be government intervention, for example if the government controls rents to ensure that lower-income families do not have to pay too much for housing.

An usual way to analyze market disequilibria is by studying price movements. Given that prices and rents may be regulated in certain segments of the housing market, it is worthwhile to investigate additional indicators of market disequilibria. The formation of stocks or of waiting lists are examples of such indicators (cf. Kornai, 1980). Therefore we will focus in this paper on the role of vacant dwellings on the housing market.

In section 2 we will give a theoretical discussion of the role of vacancies in adjustments on the housing market. We will among others pay attention to the way in which the stock of vacant dwellings is affected by residential mobility.

In sections 3 and 4 we will indicate the kind of data used in the analysis: the age composition of the vacant stock. A method will be developed to derive estimates for the number of houses leaving and entering this stock given the age composition at subsequent points in time.

Section 5 will be devoted to empirical results. We will present outcomes on vacancies, residential mobility and the duration of vacancy in the Netherlands from 1966 to 1981.

2. Vacancies on the Housing Market : Theory

Vacant houses can be looked upon from various viewpoints. A rather common view is that vacancies are undesirable: they mean a loss of scarce living accommodation which has to be reduced as much as possible given the housing shortage in many countries. Another view is that vacancies - until a certain level - are desirable: they are a prerequisite for mobility. A low number of vacant houses (especially when there is not much construction of new dwellings)

These views are not as contradictory as they may look like at first sight when one pays attention to the duration of vacancy. Houses which are vacant during a long time are not useful for a good functioning of the housing market and hence will be evaluated negatively according to both views. This is an indication that in our analysis of the stock of vacant dwellings one has to take into account the duration of vacancy.

For an analysis of the role of vacancies on the housing market in a certain region or country, we will use a stock-flow framework with households and dwellings as the basic elements. Two types of households have been distinguished:

1. households which occupy a dwelling of their own;
2. households which do not occupy a dwelling of their own.

The latter group includes among others households living in informal dwellings such as caravans and boats and households living in nursing-homes etc. Another part of this group is formed by households (not registered as principal occupants) which share a dwelling with one or more other households.

Four different categories of dwellings have been distinguished:

1. occupied dwellings;
2. vacant dwellings which have been occupied before;
3. vacant dwellings which have not been occupied before;
4. dwellings in construction.

Obviously, a stock-flow framework based on these distinctions does not allow a very refined analysis of the housing market since various important features of dwellings and households are missing. For example, no distinction is made between the sales and rental sector or between low and high income families. For the purpose of the analysis and in view of the available data in the empirical part of the study, these omissions can be justified.

The following events give rise to a change in the volume or composition of the stocks in the framework.

I. A household with a dwelling of its own leaves the dwellings:

1. it moves to a vacant dwelling which has been occupied before.
2. it moves to a vacant dwelling which has not been occupied before.
3. it moves to a new dwelling immediately after the end of the construction.
4. it leaves the region (emigration, decease).
5. it moves to a place in the region which is not registered as a dwelling.

II. A household without a dwelling of its own changes its position:
6. it moves to a vacant dwelling which has been occupied before.
7. it moves to a vacant dwelling which has not been occupied before.
8. it moves to a new dwelling immediately after the end of construction.
9. it leaves the region.

III. Other events:
10. an occupied dwelling leaves the dwelling-stock (e.g., due to fire).
11. a vacant dwelling leaves the dwelling-stock.
12. a new household enters the housing market (e.g., a household from elsewhere starts searching, children decide to leave the family where they have grown up, divorce).
13. start of the construction of a new dwelling.
14. a new dwelling becomes vacant after construction.

The stock-flow framework has been presented in Fig. 1. Let $S_i (i=1,\ldots,4)$ and $T_i (i=1,2)$ denote the size of stocks of houses and households, respectively.

Fig. 1. A stock-flow framework of the housing market.
\( F_{ij} \) denotes the flow of houses per period from state \( i \) to state \( j \) \((i, j=0,1,\ldots,4)\). \( G_{ij} \) is the flow of households per period from \( i \) to \( j \) \((i, j=0,1,2)\). If \( a_1, \ldots, a_{14} \) denote the number of houses and or households per period involved in the events 1, \ldots, 14, the following relationships hold:

\[
\begin{align*}
F_{12} &= a_1 + a_2 + a_3 + a_4 + a_5 \\
F_{21} &= a_1 + a_6 \\
F_{31} &= a_2 + a_7 \\
F_{41} &= a_3 + a_8 \\
F_{10} &= a_{10} \\
F_{20} &= a_{11} \\
F_{43} &= a_{14} \\
F_{04} &= a_{13} \\
G_{12} &= a_5 + a_{10} \\
G_{21} &= a_6 + a_7 + a_8 \\
G_{10} &= a_4 \\
G_{20} &= a_9 \\
G_{02} &= a_{12}
\end{align*}
\]

(2.1)

Note that several of the flows in the framework are interdependent. For example, \( F_{12} \) and \( F_{21} \) have \( a_1 \) in common while \( F_{12} \) and \( G_{12} \) have \( a_5 \) in common.

The relationships between stocks and flows read:

\[
\begin{align*}
S_{1,t+1} &= S_{1,t} + F_{21} + F_{31} + F_{41} - F_{12} - F_{10} \\
S_{2,t+1} &= S_{2,t} + F_{12} - F_{21} - F_{20} \\
S_{3,t+1} &= S_{2,t} + F_{43} - F_{31} \\
S_{4,t+1} &= S_{4,t} + F_{04} - F_{43} - F_{41} \\
T_{1,t+1} &= T_{1,t} + G_{21} - G_{12} - G_{10} \\
T_{2,t+1} &= T_{2,t} + G_{12} + G_{02} - G_{21} - G_{20}
\end{align*}
\]

(2.2)
In (2.2) we dropped the time index for the flows to simplify the notation. Note that \( S \) and \( T \) are equal by definition: the number of households occupying a house is equal to the number of houses which are occupied. This equality is guaranteed in (2.1): it is easy to verify that the change in \( S \) is equal to the change in \( T \):

\[
F_{21} + F_{31} + F_{41} - F_{12} - F_{10} = G_{21} - G_{12} - G_{10}
\]  

(2.3)

For an analysis of the properties of the stock-flow system described above, one has to specify the determinants of the flows. These determinants can be found by examining the behaviour of the actors in the stock-flow system: occupant households, non-occupant households, building contractors, etc.

We will sketch how the behaviour of occupant households can be studied. An occupant household may choose among the alternatives 1, 2, ..., 5 mentioned above. In addition, the household also has the zero-option to stay in its present dwelling. The preferences for these options depend a.o. on a combination of factors such as: features of present dwelling (quality, rental versus sales sector), economic factors (incomes, prices), demographic factors (composition of households), occupational mobility and the cost of mobility. For an examination of these factors as determinants of residential mobility we refer to Fredland, 1974, Rietveld, 1979 and Van Lierop and Nijkamp, 1982.

The actual behaviour of households is not exclusively a reflection of preferences, however. Some of the moves (e.g., 4 and 5) may be forced rather than voluntary. The supply conditions will certainly influence actual residential mobility. For example, many households which might prefer to move may be forced to stay in their dwellings given an excess demand for certain types of dwellings.

The stock of vacant dwellings \((S_2 + S_3)\) is sometimes used as the main indicator of imbalance between supply and demand at the housing market (cf. Snickars, 1978). According to this approach, a large stock of vacancies implies a high probability that households intending to move will indeed move. Further, a large stock of vacancies may be a signal for building contractors, to build small amounts of new housing. Snickars, 1978, shows that on the basis of these assumptions on the role of vacancies in the behaviour of the relevant actors it can be proved that a stationary state exists for a stock-flow scheme similar to Fig. 1. Furthermore, he shows that under reasonable assumptions this stationary state is a stable one. Thus, even without flexible prices, the housing market may move to a certain equilibrium.
We draw the following conclusions from this section:

1. For an analysis of the role of vacancies on the housing market, it is important to pay attention to the duration of vacancy.

2. The flows of dwellings entering and leaving the stock of vacant dwellings consist of several components, as indicated in (2.1). The shares of these components depend among others on the number of starting households, and the volumes of dwellings produced and demolished.

3. There is a two-sided relationship between stocks and flows in the stock-flow framework (Fig. 1).

On the one hand, changes in stocks are by definition determined by the sum of net flows according to (2.2). On the other hand, stocks may be determinant of the flows on the housing market.


3.1. **Introduction**

On the housing market there is usually more information available on stocks than on flows. For example, in most countries one knows more about the size and composition of population or the housing stock than about the size and composition of migration. If one wants to improve knowledge about flows, this can be done in two ways: directly and indirectly. Direct measurement of flows can be carried out by registering the flowing objects (persons, houses). In this study we will develop an indirect method by using information about the time interval that passed since the members of a stock entered that stock. Thus, in the indirect method we will make use of the 'age-composition of stocks'.

Table 1 contains an example of the basic information used in the method. The distribution of vacant dwellings among various classes of duration is known for two or more points in time.

<table>
<thead>
<tr>
<th>Number of vacant dwellings by duration of vacancy</th>
<th>0-1 months</th>
<th>1-4 months</th>
<th>4-7 months</th>
<th>7-10 months</th>
<th>&gt;10 months</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1st.</td>
<td>12000</td>
<td>24000</td>
<td>15000</td>
<td>9000</td>
<td>28000</td>
<td>88000</td>
</tr>
<tr>
<td>Oct. 1st.</td>
<td>14000</td>
<td>25000</td>
<td>13000</td>
<td>9000</td>
<td>30000</td>
<td>91000</td>
</tr>
</tbody>
</table>

Table 1. Vacant dwellings by duration of vacancy.
The table shows that although the total stock of vacancies only changed moderately (an increase of 3000 dwellings) the gross flows are much larger.

For example, of the 24000 vacant dwellings with a duration of 1-4 months at the beginning of April only 9000 are still vacant half a year later. Of the 52000 dwellings with a duration longer than 4 months the remaining number 6 months later is 30000. Thus the total number of dwellings leaving the vacant stock is at least equal to 37000 (22000 + 15000). The actual number may even be much larger since we did not yet take into account the group of dwellings x which entered the vacant stock between April and October and left it before the end of this period. Further, we did not include the number of dwellings y which were vacant on April 1st with a duration of 0-1 months and which left during the 6 months considered.

Thus the total number of houses leaving the vacant stock is equal to 37000 + x + y. Obviously, since the net flow of houses entering the vacant stock is 3000, the flow of houses entering the vacant stock is 40000 + x + y.

The unknown part of the outflow (x + y) may be a considerable part of the total outflow. A reasonable guess might be for example: x = 30000 and y = 9000, so that the known part (37000) might even be smaller than the unknown part. We conclude, therefore that it is important to develop a reliable estimation technique for x and y if one wants to know the flows of houses entering and leaving the vacant stock.

This section will be devoted to the introduction of a number of concepts necessary for such an estimation technique. In the following section the estimation technique itself will be presented.

3.2. Continuation Functions: Homogeneous Dwellings

Consider a dwelling which becomes vacant at time 0.

We define the continuation function $p(t)$ of the dwelling as the probability that the dwelling is still vacant after a time interval $t$. The function $p(t)$ has to satisfy the following requirements: $p(0)=1$, $p(t) \geq 0$ and $p'(t) \leq 0$.

Assume that the probability of leaving the vacant stock is constant in the course of time. Consequently, the probability that the dwelling leaves the vacant stock during an infinitesimal short period $\Delta t$ may be set equal to $c \Delta t$, where $c \geq 0$ and where the quit rate $c$ does not depend on the time the dwelling has already been vacant. Given this assumption we find for $p(t)$:
\[ p(t) = \lim_{\Delta t \to 0} (1-c \Delta t)^{t/\Delta t} \quad t \geq 0 \] (3.1)

Let \( n = \frac{t}{\Delta t} \). Then (3.1) can be rewritten as:

\[ p(t) = \lim_{n \to \infty} (1-ct/n)^n \quad t \geq 0 \] (3.2)

Thus we find:

\[ p(t) = \exp (-ct) \quad t \geq 0 \] (3.3)

As can be checked easily, (3.3) satisfies the requirements imposed above.

A specific feature of the \( p(t) \) function in (3.3) is:

\[ \frac{p(t+t_1)}{p(t)} = \exp (-ct_1) \] (3.4)

Hence, for this \( p(t) \) function the probability that the dwelling remains vacant during a period of the length \( t_1 \) does not depend on the length of the preceding period of vacancy.

Continuation functions may also refer to groups of dwellings rather than individual dwellings. Consider for example a cohort of dwellings entering the vacant stock at a certain point in time. Then the continuation function \( p^c(t) \) of the cohort is defined as the expected share of the cohort which is still vacant after a time interval \( t \). If we may assume that the cohort is homogeneous (all members of the cohort are subject to the same continuation function), it is clear that the cohort continuation function \( p^c(t) \) is identical to the individual continuation functions \( p(t) \).

3.3. Continuation Functions : Heterogeneous Dwellings

In Section 3.2., we found that individual and cohort continuation functions are identical under the assumption of homogeneity of the cohort. In the present section we will examine this relationship when the members of a cohort are heterogeneous. The dwellings in a cohort may differ, according to price, quality, location, behaviour of owner, etc. and this will influence their probability of remaining in the vacant stock. If a cohort consists of \( N \) dwellings and if the individual continuation functions are \( p_1(t), \ldots, p_N(t) \),
the cohort continuation function is:

\[ p^c(t) = \frac{1}{N} \sum_n p_n(t) \quad (3.5) \]

Assume that the individual continuation functions have the exponential form (3.3). Further, assume that the cohort consists of heterogeneous dwellings: each dwelling \( n \) gives rise to a different parameter \( c_n \) in (3.3). More specifically, we will assume that the quit rate \( c \) of a certain dwelling in the cohort is drawn from a continuous probability distribution \( g(c) \) which is non-negative for non-negative values of \( c \). Thus, we arrive at:

\[ p^c(t) = \int_0^\infty g(c) \exp(-ct) dc \quad t \geq 0 \quad (3.6) \]

so that \( p^c(t) \) can be interpreted as the moment generating function of \( g(c) \) (apart from the minus sign).

We will assume that \( g(c) \) is the gamma distribution \(^2\):

\[ g(c) = \frac{1}{\Gamma(\alpha)\beta^\alpha} c^{\alpha-1} \exp\left(-\frac{c}{\beta}\right) \quad , \quad c > 0 \]

\[ = 0 \quad \text{elsewhere} \quad (3.7) \]

where the parameters \( \alpha \) and \( \beta \) are non-negative.

Given this assumption we find for \( p^c(t) \):

\[ p^c(t) = (1+\beta t)^{-\alpha} \quad t \geq 0 \quad (3.8) \]

We will now examine whether the expected share of the cohort which remains vacant during a time period \( t_1 \) depends on the preceding period of vacancy \( t \). Therefore we compute:

\[ \frac{p^c(t+t_1)}{p^c(t)} = (1 + \frac{\beta t_1}{1+\beta t})^{-\alpha} \quad (3.9) \]

so that the conclusion is that this share depends indeed on \( t \). The longer the preceding period of vacancy \( t \), the higher the expected share of the cohort which remains vacant. The reason for this slowing-down of the outflow from the vacant stock is obviously that dwellings with a high quit rate will on average leave the vacant stock earlier than other dwellings. Hence, the composition of the cohort is gradually changing: the share of dwellings with
a low probability to leave the vacant stock increases more and more in the course of time.

3.4. The Distribution of Durations of Vacancy

We will now examine the composition of the vacant stock: is it possible to say something about the distribution of the durations of vacancy when one knows the continuation function \( p^c(t) \)?

Obviously, the vacant stock at a certain time consists of the remains of all cohorts of dwellings which entered that stock in previous periods. Thus, the size and composition of the vacant stock depend on the size of the cohorts and which entered before and the corresponding \( p^c(t) \) functions.

Concerning the entry of vacant dwellings we will assume that the dwellings enter independent from each other. Thus when \( N \) dwellings enter per period, the expected number of entrants during a time interval \( \Delta t \) is \( N \Delta t \) for all time intervals of this length.

We will study the composition of the vacant stock under the assumption that this stock is in a stationary state: the size of the cohorts is constant over time, and besides all cohorts have the same continuation function.

Let \( N \) be the inflow of vacant dwellings per time unit. Consider an infinitesimal short time period \( \Delta t \). The expected size of a cohort entering the vacant stock during such a time period is \( N \Delta t \). After a period of length \( t \) the expected size of the cohort has been decreased until \( N p^c(t) \Delta t \).

Thus the distribution \( f_s(t) \) of the expected number of dwellings in the vacant stock according to their duration of vacancy \( t \) can be found by inspecting the expected size of the remains of all cohorts which entered before. This distribution is proportional to \( p^c(t) \):

\[
 f_s(t) = \frac{p^c(t)}{\int_0^\infty p^c(t) \, dt} \quad (3.10)
\]

Note that by including the denominator it is guaranteed that \( \int_0^\infty f_s(t) \, dt = 1 \), assuming that \( \int_0^\infty p^c(t) \, dt \) is finite.

Along the same line of reasoning we find for the expected size \( V \) of the vacant stock:
Note that \( f \) refers to vacancies which are in the vacant stock at a certain moment. It is also meaningful to look at the vacancies which are leaving this stock at a certain moment. The distribution of the expected number of vacant dwellings according to their duration of vacant \( t \) when they are leaving the vacant stock will be denoted as \( f_1(t) \).

It is not difficult to see that \( f_1(t) \) is equal to:

\[
 f_1(t) = -\frac{dP_c(t)}{dt}
\]  

(3.12)

In this case there is no need to include a denominator such as in (3.10), since

\[
 \int_0^\infty f_1(t) dt = p_c(0) - \lim_{t \to \infty} p_c(t)
\]  

(3.13)

which is equal to 1, since \( p_c(0) = 1 \) by definition and \( \lim_{t \to \infty} p_c(t) = 0 \) since otherwise the vacant stock would not be finite.

Further, the expected volume \( L \) of the flow leaving the vacant stock per period is:

\[
 L = N \int_0^\infty -\frac{dp_c(t)}{dt} dt = N
\]  

(3.14)

so that the expected outflow is equal to the inflow, which is obviously not a surprise given the assumption of stationarity.

The functions \( f_\delta \) and \( f_\delta_1 \) can be used to determine the mean durations of vacancy \( \delta \) and \( \delta_1 \) referring to the stock of vacant dwellings and the flow of dwellings leaving the vacant stock, respectively:

\[
 \delta = \int_0^\infty t p_c(t) dt / \int_0^\infty p_c(t) dt
\]  

(3.15)

\[
 \delta_1 = \int_0^\infty -t \frac{dp_c(t)}{dt} dt = \int_0^\infty p_c(t) dt
\]  

(3.16)

The latter equality holds when \( \lim_{t \to \infty} tp_c(t) = 0 \).
When one substitutes (3.16) into (3.11) one finds the following fundamental result:

\[ V = N \delta \]  

(3.17)

Thus in the stationary state the expected size of the vacant stock is equal to the volume of the inflow per period times the mean duration of vacancy of the dwellings leaving the stock.

It is interesting to determine \( f_s(t) \), \( f_l(t) \), \( \delta_s \) and \( \delta_l \) for \( p(t) \) as defined in (3.8). The results are:

\[ f_s(t) = (\alpha-1) \beta (1+\beta t)^{-\alpha} \]  

(3.18)

\[ f_l(t) = \alpha \beta (1+\beta t)^{-\alpha-1} \]  

(3.19)

\[ \delta_s = \frac{1}{(\alpha-1) \beta} \]  

(\( \alpha > 2 \))

(3.20)

\[ \delta_l = \frac{1}{(\alpha-1) \beta} \]  

(\( \alpha > 1 \))

(3.21)

Thus for this particular \( p(t) \) function we find that \( \delta_s > \delta_l \) : the duration of the dwellings in the vacant stock is larger than the mean duration of the dwellings leaving the vacant stock. This is essentially the same phenomenon of the selective quits as the one discussed at the end of section 3.3. It is directly related to the assumption that the dwellings entering the vacant stock are heterogeneous.

If one assumes that the cohorts of dwellings entering the vacant stock are homogeneous and have continuation functions as in (3.3) one finds:

\[ f_s(t) = f_l(t) = c e^{-ct} \]  

(3.22)

\[ \delta_l = \delta_s = \frac{1}{c} \]  

(3.23)

Thus, when the vacant dwellings are homogeneous, the durations \( \delta_s \) and \( \delta_l \) are equal. It can be shown that all \( p(t) \) functions of the type (3.6) give rise to the selective quit phenomenon, and hence to the result: \( \delta_s > \delta_l \).

In Table 1 we have already shown the type of data available for the estimation of the inflow to and outflow from the vacant stock. When these data are confronted with \( f_s(t) \) as defined in (3.18) or (3.22) it is in principle possible to determine values of \( \alpha \) and \( \beta \) (or \( c \)) which give rise to a best fit between the theoretical and observed distribution. Once \( \alpha \) and \( \beta \) are known, one can easily determine \( \delta_1 \) by means of (3.21) and subsequently the inflow \( N \) by means of (3.17).

We will not follow this approach, however, since the theoretical distribution \( f_s(t) \) is based on a stationarity assumption, which is a questionable one for the vacant stock for several reasons:

1. Seasonal fluctuations in the construction of new dwellings give rise to fluctuations in the inflow of vacant dwellings.
2. On the housing market sudden changes may occur in the supply-demand relationships which may give rise to sudden changes in the inflow of new vacant dwellings.
3. The changes mentioned above may also have an influence on the velocity of the outflow from the vacant stock and hence on the continuation function \( p^c(t) \).

Thus if one yet would employ the estimation method sketched above, it would be impossible to take into account that a large share of vacant dwellings with a long duration (say one year and longer) may be due to an exceptional large inflow one to three years ago. In such a case the relevant frame of reference for the number of dwellings with a long duration is not the size of the total vacant stock at that time, but rather the size of the inflow one to three years ago. This is the main idea of the estimation method to be developed here: estimates of \( \alpha, \beta \) and \( N \) have to be based on a comparison of the distribution of durations of vacancy at various points in time.

The estimation method relies on two basic assumptions. The first assumption is that during the period (six months) between two points of time for which the distribution of durations of vacancy is given, the continuation functions do not change. They may be different for different periods.

The second assumption is that during the period considered, the share of dwellings arriving in the vacant stock is constant. This share may differ from period to period.
On the basis of the first assumption the course of a cohort can be described as follows. Consider a cohort of size $N\Delta t$ entering the vacant stock $t$ months before the end of a six months period ($t \leq 6$). This period will be called period 1. At the moment of entrance the distribution of the quit rate $c$ is $g_1(c)$. At the end of the first period the distribution of $c$ in the remains of the cohort, $h_1(c,t)$, is:

$$h_1(c,t) = \frac{g_1(c) \exp(-ct)}{\int_0^\infty g_1(c) \exp(-ct) dc}$$  \hspace{1cm} (4.1)

The expected size of the cohort at this moment is

$$N\Delta t \cdot p_1^c(t)$$  \hspace{1cm} (4.2)

where $p_1^c(t)$ is:

$$p_1^c(t) = \int_0^\infty g_1(c) \exp(-ct) dc$$  \hspace{1cm} (4.3)

At the beginning of the second period of six months the distribution of quit rates for the new cohorts changes from $g_1(c)$ to $g_2(c)$ and it remains unchanged during the rest of that period. For the cohorts which arrived in the first period, this means that $h_1(c,t)$ changes into:

$$h_2(c,t) = \frac{g_2(c) \exp(-ct)}{\int_0^\infty g_2(c) \exp(-ct) dc}$$  \hspace{1cm} (4.4)

By means of (4.3) we can compute the expected size of the cohort at the end of the second period:

$$N\Delta t \cdot p_1^c(t) \cdot p_2^c(t+6) / p_2^c(t)$$  \hspace{1cm} (4.5)

where $p_2^c(t)$ is:

$$p_2^c(t) = \int_0^\infty g_2(c) \exp(-ct) dc$$  \hspace{1cm} (4.6)

The further development of the cohort can easily be described by extensions of formulas (4.4) and (4.5).
We will now examine the distribution of the expected numbers of vacant dwellings according to their duration of vacancy at the beginning of a certain period $t$ on the basis of the results obtained above. Let $A_i(t)$ denote the expected number of vacant dwellings with a duration of vacancy between $i-1$ and $i$ months at the beginning of period $t$. Let $N_i(t)$ denote the number of vacant dwellings which entered during the $i$-th month ($i \leq 6$) before the end of period $t$. Then $A_{t+1}(1), \ldots, A_{t+1}(6)$ can be determined by means of (4.2) as follows:

\[
\begin{align*}
A_{t+1}(1) &= N_{t-1}(1) \int_0^1 p^c(t) \, dt \\
&\vdots \\
A_{t+1}(6) &= N_{t-1}(6) \int_0^6 p^c(t) \, dt
\end{align*}
\]

where $p^c$ is the continuation function during period $t$.

For the determination of $A_{t+1}(7), \ldots, A_{t+1}(12)$ one can make use of (4.5) to arrive at:

\[
\begin{align*}
A_{t+1}(7) &= N_{t-1}(1) \int_0^1 p^c(t+6) \frac{p^c(t) \, dt}{p^c(t)} \\
&\vdots \\
A_{t+1}(12) &= N_{t-1}(6) \int_5^6 p^c(t+6) \frac{p^c(t) \, dt}{p^c(t)}
\end{align*}
\]

Thus:

\[
\begin{align*}
A_{t+1}(7) &= A_{t+1}(1) \int_0^1 p^c(t+6) \frac{p^c(t) \, dt}{p^c(t)} / \int_0^1 p^c(t) \, dt \\
&\vdots \\
A_{t+1}(12) &= A_{t+1}(6) \int_5^6 p^c(t+6) \frac{p^c(t) \, dt}{p^c(t)} / \int_5^6 p^c(t) \, dt
\end{align*}
\]
So we conclude that it is possible to express $A_{\tau+1}(7), \ldots, A_{\tau+1}(12)$ in terms of 1) expected values of stocks six months before and 2) continuation functions of the periods $\tau$ and $\tau-1$. Results for $A_{\tau+1}(13), A_{\tau+1}(14), \ldots,$ can be obtained in a similar way.

For practical purposes (4.9) gives rise to computational difficulties since there are hardly relevant functions $p^c_t(t)$ for which the integration at the right hand side of (4.9) can be carried out by means of analytical methods. This difficulty can be solved by using

$$a_t(i) = \frac{\int_{i-1}^{i} p^c_t(t+6) \, dt}{\int_{i-1}^{i} p^c_t(t) \, dt} \quad (4.10)$$

as an approximation for

$$\int_{i-1}^{i} \frac{p^c_t(t+6)}{p^c_t(t)} \, dt / \int_{i-1}^{i} p^c_{t-1}(t) \, dt \quad (4.11)$$

where $i = 1, 2, \ldots, 6$. In Appendix 1 we show that (4.10) is indeed a quite reasonable approximation for (4.11). Given this result it is not difficult to see that $a_t(i)$ can also be used to approximate the transition from $A_t(i)$ to $A_{\tau+1}(i+6)$ for $i > 6$.

The transition probability $a_t(i)$ as defined in (4.10) plays an important role in the estimation method which will be described now. The method is based on the following assumptions.

1. The continuation function $g^c_t(c)$ remains unchanged during period $\tau$ of six months length. The underlying distribution of quit rates $g_t(c)$ is gamma-distributed with parameters $\alpha_t$ and $\beta_t$ (see 3.7).

2. During period $\tau$ a constant but unknown proportion $\gamma_t$ of the occupied housing stock enters the vacant stock:

$$N_t(1) = \ldots = N_t(6) = \gamma_t S_t \quad (4.12)$$

where $S_t$ is the stock of occupied dwellings at the beginning of period $\tau$.

3. Information is available on the number of vacant dwellings with durations of vacancy as shown in Table 1 at the beginning of period $\tau+1$. 
\[B_{t+1}(1) : 0 - 1 \text{ months of vacancy}\]
\[B_{t+1}(2) : 1 - 4 \text{ months of vacancy}\]
\[B_{t+1}(3) : 4 - 7 \text{ months of vacancy}\]
\[B_{t+1}(4) : 7 - 10 \text{ months of vacancy}\]
\[B_{t+1}(5) : > 10 \text{ months of vacancy}\]

4. We know the actual number of vacant dwellings with a duration between 
\(i-1\) and \(i\) months at the beginning of period \(t\) for all \(i \geq 1\).
These numbers will be denoted by \(A_t(i)\).

5. The parameters \(\alpha_t\), \(\beta_t\) and \(\gamma_t\) are estimated by means of the follow-
ing non-linear least squares problem (the subscript \(\tau\) has been deleted 
from \(\alpha\), \(\beta\) and \(\gamma\) to simplify the notation):

\[
\min_{\alpha,\beta,\gamma} \sum_{i=1}^{5} e_i^2
\]

where

\[
e_1 = B_{t+1}(1) - \gamma S_t b_t(1)
\]
\[
e_2 = B_{t+1}(2) - \gamma S_t (b_t(2) + b_t(3) + b_t(4))
\]
\[
e_3 = B_{t+1}(3) - \gamma S_t (b_t(5) + b_t(6)) - \overline{A}_t(1) \cdot a_t(1)
\]
\[
e_4 = B_{t+1}(4) - \overline{A}_t(2) a_t(2) - \overline{A}_t(3) a_t(3) - \overline{A}_t(4) a_t(4)
\]
\[
e_5 = B_{t+1}(5) - \overline{A}_t(5) a_t(5) - \overline{A}_t(6) a_t(6) - \ldots
\]

and

\[
b_t(i) = \int_{i-1}^{i} (1+\beta t)^{-\alpha} dt = \frac{(1+(i-1)\beta)^{1-\alpha} - (1+i\beta)^{1-\alpha}}{(\alpha-1)\beta} \quad (i=1,\ldots,6)
\]
\[
a_t(i) = \frac{\int_{i-1}^{i} (1+\beta(t+6))^{-\alpha} dt}{\int_{i-1}^{i} (1+\beta t)^{-\alpha} dt} = \frac{(1+(i+5)\beta)^{1-\alpha} - (1+(i+6)\beta)^{1-\alpha}}{(1+(i-1)\beta)^{1-\alpha} - (1+i\beta)^{1-\alpha}} \quad (i=1,2,\ldots)
\]

Various algorithms have been developed to solve non-linear minimization prob-
lems. For this particular case we made use of the Levenberg-Marquardt algo-
rithm (see Marquardt, 1963) with satisfactory results.
Once $\alpha$, $\beta$ and $\gamma$ have been estimated for period $\tau$, the inflow of vacant dwellings per month can be computed as $\gamma S_\tau$. The outflow per month in period $\tau$ is by definition equal to $\gamma S_\tau + \sum \frac{1}{6} T_{1} \epsilon_{1}(i) - \sum \frac{1}{6} T_{1} \epsilon_{1}(i)$. The values of $\alpha$ and $\beta$ can be used to estimate the mean duration of vacancy of dwellings by means of (3.20) and (3.21).

In order to start the computations for period $\tau+1$, first the values of $A_{\tau+1}(1)$, $A_{\tau+1}(2)$,... have to be determined. This can be done by applying the transition probabilities $b(i)$ and $a(i)$ to $\gamma S_\tau$ and $A_\tau(i)$, respectively. For the first period, this cannot be done, obviously, so that in that case one should start with good guesses.

The estimation procedure (4.13) will be applied to data on two kinds of vacant dwellings: dwellings which have been occupied before, and newly constructed dwellings which have not yet been occupied (see also Fig. 1). For the second group of dwellings a minor modification of (4.13) has to be carried out, related to the second assumption. For the entry of newly constructed vacant dwellings the housing stock is no longer the relevant source, as assumed in (4.12), but obviously the flow of new dwellings constructed. Some of these dwellings will not become vacant at all: they are occupied immediately after the end of the construction period (see Fig. 1). Therefore, for newly constructed dwellings, (4.12) is replaced by:

$$N_{\tau}(i) = \gamma F_{\tau}(i) \quad (4.12')$$

where $F_{\tau}(i)$ is the number of dwellings of which the construction finished $i$ months before the end of period $\tau$. This modification gives rise to some minor changes in the definition of $e_1$, $e_2$, and $e_3$ in (4.13).

Note that $\gamma_\tau$ has different dimension in (4.12) and (4.12'). In (4.12), the dimension is [1/time] which indicates that $\gamma_\tau$ is the rate of outflow from the occupied housing stock. In (4.12'), $\gamma_\tau$ is dimensionless: it indicates the fraction of a flow of houses which becomes vacant.

5. **Empirical Results**

Since 1966 the municipalities in the Netherlands measure two times a year (April, 1st, and October, 1st) the number of vacant dwellings according to their duration of vacancy. A distinction is made between vacant dwellings
which have been occupied before and dwellings which have become vacant immediately after construction. In Appendix 2 we give more details on the way in which the measurement takes place. Unfortunately no information is available on the features of vacant dwellings.

The national figures for the stock of vacant dwellings which have been occupied before is represented in Table 2. It displays a rather steady growth of vacancies: from approximately 31000 in 1966 to the triplicate in 1981 (approximately 96000). Compared with the total stock of dwellings the increase is less dramatic: from circa 1% in 1966 to circa 2% in 1981. The most rapid growth in the number of vacancies takes place between the years 1970 and 1974: from approx. 1.1% to approx. 1.9%. After 1974 the share of vacant dwellings in the total housing stock remains relatively stable.

<table>
<thead>
<tr>
<th>Duration of Vacancy</th>
<th>Number of Vacant Dwellings</th>
<th>Share of Vacant Dwellings in Housing Stock (%)</th>
</tr>
</thead>
<tbody>
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<td>0-1</td>
<td>7313</td>
<td>.95</td>
</tr>
<tr>
<td>1-4</td>
<td>7834</td>
<td>1.02</td>
</tr>
<tr>
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<td>8200</td>
<td>1.05</td>
</tr>
<tr>
<td>7-10</td>
<td>8595</td>
<td>1.12</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>9154</td>
<td>1.21</td>
</tr>
<tr>
<td>Total</td>
<td>31141</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Table 2. Vacant dwellings which have been occupied before according to their duration of vacancy.
The share of the dwellings with a long duration of vacancy (longer than 10 months) is clearly larger in the last years than in the first years, which indicates that the continuation function has changed in the course of time.

The data contained in Table 2 have been used to estimate the parameters $\alpha$, $\beta$, and $\gamma$ in (4.13) for each of the 31 subsequent periods. For some periods we found rather deviating values for the parameters which can be explained, among others, by the small number of degrees of freedom (5 observations and 3 parameters give rise to only 2 degrees of freedom).

Therefore we fixed one parameter ($\beta$) on the median value found for the 31 periods: $\beta = .21$. Given this value of $\beta$, we estimated again $\alpha$ and $\gamma$ for each of the 31 periods. The results are shown in Table 3. The goodness-of-fit measured according to $R^2$ is still reasonable and only slightly less compared with the $R^2$ obtained in case of 3 estimated parameters. We did not examine the statistical significance of the parameters since also in the case of 2 estimated parameters the number of degrees of freedom is still very small.

<table>
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<tr>
<th></th>
<th>$\alpha$</th>
<th>$\gamma/1000$</th>
<th>$\beta$</th>
<th>$\delta$</th>
<th>$R^2$</th>
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<td>3.15</td>
<td>.21</td>
<td>5.61</td>
<td>.996</td>
</tr>
</tbody>
</table>

Table 3. Estimation results for dwellings which have been occupied before.
The development of the parameter $\gamma$ in the course of time is quite remarkable. This parameter indicates the proportion of dwellings which monthly enters the vacant stock. It increases gradually from 2.7 °/oo in 1967 to 4.6 °/oo in 1974 and decreases afterwards to 3.6 °/oo in 1979 after which it increases again slightly.

We conclude that by means of the estimation method developed in this paper one can reveal that considerable changes took place in residential mobility. We will not examine here in detail which factors contributed to these changes. We conjecture that the fast increase in residential mobility after 1971 is due to a combination of factors: a large increase in income, exceptionally high production figures for new dwellings and a high rate of inflation compared with the rate of interest which induced many people to move from the rental to the sales sector.

The velocity of outflow from the vacant stock is indicated by $\delta_1$, which is equal to $1/((\alpha-1)\beta)$ according to (3.21). This variable indicates the mean duration of vacancy of dwellings leaving the vacant stock which would arise when $\alpha$ and $\beta$ would be constant for a longer time. The mean duration decreases from approx. 4.0 months in 1967 to approx. 3.3 months in 1970. Then it increases gradually until approx. 5.9 months in 1979, after which it remains at relatively high levels. The development of $\delta_1$ reveals that it takes more and more time to find a new occupant for a house which is left by its occupants. At the end of the seventies the housing market is presumably less tight than at the beginning of the seventies. Unfortunately no information is available on the types of dwellings according to their duration of vacancy. It is well known that this duration may vary considerably (see e.g. Hartog, 1981). One should be careful with drawing definite conclusions concerning the tightness of the housing market since changes in the mean duration of vacancy may among others be due to changes in the shares of various types of dwellings in the vacant stock.

Given the development in $\gamma$ and $\delta_1$ we may conclude that the strong increase in the number of vacant dwellings from 1970 to 1975 was due to a simultaneous increase in residential mobility and an increase in the duration of vacancy. The relatively stable level of vacancy after 1974 is the result of 2 countervailing forces: a gradual decrease of residential mobility and an increase in the mean duration of vacancy.
After the analysis of vacant dwellings which have been occupied before, we will pay attention to new vacant dwellings: dwellings which become vacant immediately after construction. In Table 4 the development of the stock of new vacant dwellings since 1966 is represented. When one compares Tables 2 and 4, one finds that the new vacant dwellings contribute appr. 5 to 20% to the total vacant stock. The fluctuations in the stock of new vacant dwellings are much larger than in the stock of already existing vacant dwellings. For example in 1970 we observe 4300 new vacant dwellings and in 1973 19600 of such dwellings. These fluctuations are due to the relatively long period between the moment when the decision is taken to build a dwelling and the end of construction. During this period the supply-demand relationship may change considerably.

<table>
<thead>
<tr>
<th>Number of vacant dwellings according to duration of vacancy measured in months.</th>
<th>vacant stock divided by average monthly production volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-1</td>
</tr>
<tr>
<td>Oct.66</td>
<td>255</td>
</tr>
<tr>
<td>Apr.67</td>
<td>285</td>
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<td>Oct.67</td>
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</tr>
<tr>
<td>Oct.81</td>
<td>163</td>
</tr>
</tbody>
</table>

Table 4. New vacant dwellings according to their duration of vacancy.

In the last column of Table 4 we compare the volume of the vacant stock of new dwellings with the average monthly production volume during the preceding six months. The conclusion is that the vacant stock never exceeds the average production volume of 1.7 months.
The estimation of the parameters $\alpha$, $\beta$, and $\gamma$ has been carried out in a way similar to the case of dwellings which have already been occupied before. First the three parameters have been estimated for the 31 subsequent periods. Subsequently, $\beta$ has been fixed on its median value (.26), after which $\alpha$ and $\gamma$ have been estimated. The results can be found in Table 5.

<table>
<thead>
<tr>
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<th>$\alpha$</th>
<th>$\gamma$</th>
<th>$\beta$</th>
<th>$\delta_1$</th>
<th>$R^2$</th>
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<td>.28</td>
<td>2.65</td>
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<td>993</td>
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<td>.29</td>
<td>2.44</td>
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<td>.25</td>
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<td>6.13</td>
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<td>1.53</td>
<td>.45</td>
<td>7.25</td>
<td>982</td>
<td></td>
</tr>
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</table>

Table 5. Estimation results for new vacant dwellings.

The share of dwellings $\gamma$ which become vacant immediately after construction is relatively stable: most of its values are assumed between .25 and .35. This means that around 70% of the houses constructed per period become occupied immediately after the end of construction. The mean duration of vacancy $\delta_1$ varies to a larger extent: from less than two months to around 8 months. Thus it appears that variations in the stock are to a larger extent due to variations in the duration of vacancy than to variations in the share of dwellings which become vacant.
Comparing Tables 5 and 3 we note that the duration of vacancy of new dwellings is in most years smaller than for dwellings which have been occupied before. The exceptions occur in years of extreme slumps on the housing market: 1973, 1980 and 1981.

6. Concluding Remarks

The estimation method developed can be considered as a general tool to determine the volume of flows given the age composition of stocks. It is not only applicable to stocks and flows on the housing market, but it can also be used in other cases, e.g. the labour market.

In this particular study, the estimation method has been used to determine a special aspect of residential mobility: the total number of existing dwellings which become available for new occupants during a certain period. This is an important piece of information if one wants to investigate the opportunities of households searching for a dwelling.

The character of this paper was exploratory; we tried to determine the volumes of some flows on the housing market without the aim to explain the results. In another study we hope to carry out an explanatory analysis of the results. Further on we intend to use the estimation method for regional housing markets rather than the national market.

Notes

1. The author thanks Koos Sneek for his comments on an earlier version of this section.

2. Also other distributions may be adopted for $g(c)$. The advantage of the gamma function is that it gives rise to functional forms which can be treated in an analytical way: it is not necessary to use numerical methods.
Appendix 1  Approximation of Transition Probabilities

In Section 4 we propose to use:

\[ a(i) = \frac{\int_{i-1}^{i} p_{i}^{c}(t+6) \, dt}{\int_{i-1}^{i} p_{i}^{c}(t) \, dt} \]

as an approximation for:

\[ \bar{a}(i) = \frac{\int_{i-1}^{i} p_{i}^{c}(t) \, dt}{\int_{i-1}^{i} p_{i}^{c}(t) \, dt} \]

We will give some numerical examples to show that this approximation is reasonably accurate.

Assume that \( p^{c}(t) \) is based on a gamma-distributed quit rate:

\[ p^{c}(t) = (1+\beta t)^{-\alpha} . \]

We will check the approximation for some values of \( \alpha \) and \( \beta \) which allow one to compute \( \bar{a}(i) \) in an analytical way.

**Case 1.**

\[
\begin{align*}
\alpha_{i-1} &= 1.0 \\
\beta_{i-1} &= 0.5 \\
\beta_{i} &= 0.3
\end{align*}
\]

\[
\begin{align*}
a_{i}(1) &= 0.38794 & \bar{a}_{i}(1) &= 0.38719 \\
a_{i}(6) &= 0.59510 & \bar{a}_{i}(6) &= 0.59505
\end{align*}
\]

**Case 2.**

\[
\begin{align*}
\alpha_{i-1} &= 2.0 \\
\alpha_{i} &= 1.0 \\
\beta_{i-1} &= 0.2
\end{align*}
\]

\[
\begin{align*}
a_{i}(1) &= 0.47724 & \bar{a}_{i}(1) &= 0.47653 \\
a_{i}(6) &= 0.63607 & \bar{a}_{i}(6) &= 0.63590
\end{align*}
\]

Thus the difference is at most ca. 0.2% in these cases. Note that the difference decreases with increasing \( i \).
Appendix 2 The Measurement of Vacancies

In the Netherlands the measurement of the stock of vacant dwellings is carried out by the ca. 800 municipalities. Citizens are obliged to inform their municipality about moves. This information is not only used for keeping the personregister, but also the dwellingsregister. Thus the municipalities are able to registrate whether and when dwellings start or end vacancy.

Two types of vacant dwellings are distinguished:

- dwellings which have been occupied before and
- dwellings which have just been built.

There are several reasons why the administrative vacancy is not identical to the actual vacancy. House-owners may have reason to conceal that their house has become vacant. People may wittingly stay at another residence than where they are registered. In addition to these more or less illegal reasons there are also other reasons for a discrepancy between administrative and actual vacancy. People may inform their municipality too late about a move. Thus the old dwelling may be registered as occupied while in reality it is already vacant while for the new dwelling the reverse holds true. Such a discrepancy does not give rise to a wrong estimation of vacancy, however, since the effect cancel each other.

An overestimation of the vacant stock arises when starting households inform the municipalities too late about their moves: they do not leave vacant dwellings. Overestimation may also take place when households move from one municipality to another. In that case first the old municipality has to be informed about the move so that there a vacant dwelling is registered. It may take time, however, before the new municipality is informed so that there an occupied dwelling is wrongly registered as vacant. Another source of overestimation of the vacant stock arises when a vacant dwelling is demolished which may be registered too late.

Finally we note that the administrative vacancy also includes 'gekraakte' dwellings (dwellings occupied by the squatter movement) and dwellings which are temporarily vacant due to renovation.
To which extent do the data form a useful and reliable basis for the estimations carried out in this paper?

We note several problems.

1. The discrepancy between the actual and administrative vacancy may not only give rise to a wrong figure for the actual vacant stock, but also for the distribution of vacancies. When the estimation method is used it may lead to wrong estimations of the mean duration of vacancy and of the inflow and outflow of vacant dwellings.

2. Municipalities check from time to time whether the administrative vacancy is in agreement with the actual vacancy in order to reduce the discrepancy as much as possible. The intensity of the check may vary in the course of time, however, which may give rise to considerable fluctuations in the administrative vacancy.

3. In some cases the municipalities appear to produce inconsistent observations on vacancy.

Consider for example:

<table>
<thead>
<tr>
<th></th>
<th>Number of vacant dwellings according to duration of vacancy in months:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-1</td>
</tr>
<tr>
<td>Apr., 1st</td>
<td>10</td>
</tr>
<tr>
<td>Oct., 1st</td>
<td>8</td>
</tr>
</tbody>
</table>

This table includes a transition from 20 to 22 which is logically impossible.

4. For most times of observation, one or several of the ca. 800 municipalities failed to carry out the measurement of the vacant stock. Thus the national figures do not always cover all municipalities.

5. The time series of observations runs from Oct. 1966. It contains some gaps, however: no observations are available for Oct. 1967, April 1971, Oct. 1971 and Oct. 1972. We have made guesses for these missing observations to be able to carry out an united analysis from Oct. 1966 to present.

We conclude that the quality of the data is not impressive. Consequently, one should be very careful in the interpretation of the estimation results.
References


Kornai, J., Economics of Shortage, North Holland, Amsterdam, 1980.

Lierop, W. van, and P. Nijkamp, Perspectives of Disaggregate Choice Models on the Housing Market, Research Memorandum, Dept. of Economics, Free University, Amsterdam, 1982.


