# The Markets for Land, Housing, and Housing Services: An Empirical Study over Time

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## 1. Introduction

A lot of empirical studies has been done both on the land and on the housing markets. But as far as I know no attention has been paid to the interdependence between these markets over time. The purpose of this paper is to determine land prices and rents simultaneously by means of a short-term forecasting model which consists of four structural equations and three identities.

In section 2 the model is presented. The markets for land will be explained by both a supply and a demand function. The gross change in the stock of housing units, i.e. the completed dwellings per time unit, is represented by an investment function which shows the demand of the owner of buildings. Finally, the tenant's demand for new housing services, i.e. the services from the net change in the stock of housing units, is given by a consumption function. In the third section the empirical analysis is shown. Explanations are given as to the data used as well as to the limits of the data material. Particular emphasis has been laid on the determination of the lag structure by means of data not used in the model itself. In the next step we give the results of the structural equations, those of the derived reduced form with standard deviations of the coefficients, and those of the forecasts of the endogenous variables with standard deviations obtained from SELS, 2SLS, and 3SLS.

The empirical analysis is restricted to three urban centers, namely the Swiss cities Zürich, Bern, and Basel. The increase of the real land prices of about 13 times in 20 years exceeds by far the figures for Philadelphia or for Israel which have been published by *Adams* et al. [1]. Therefore, it is assumed that the Swiss level of land prices could be the highest of all even if one considers the maximum rate of occupancy of the lot. (The price of a lot which is reserved for six-storey business buildings only at the Bahnhofstrasse in Zürich, i.e. the very center of the city, is estimated to be about 30,000 SFr/m$^2$ which is approximately 1,000 \$/sq.ft.) The basic models of land use, see for instance *Muth* [15] and *Alonso* [3], suggest that at least the characteristic "accessibility" of the commodity land should be introduced into a model of urban residential land use. The same can be said for the commodity housing. This would require pooled cross section and time series data for the model

[1] Revised version of my paper which was presented at the European Meeting of the Econometric Society in Grenoble (France) 1974.

in question; but this cannot be done due to the lack of statistical data. However, it is assumed that this lack does not weigh heavily because (1) only lots and dwellings are considered which lie within the municipality of the three urban centers mentioned, (2) the area of the municipalities which do not underlie any political change as to their size is relatively small when compared to that of the corresponding standard metropolitan areas, (3) transactions of lots and construction of dwellings mostly took place between the edge of the central business districts and the periphery of the municipalities, and (4) the facts above suggest that the accessibility or the distance of the lots and dwellings from the CBD do not vary too much. For these reasons it is assumed that in the special case in question all data observed stem from the same location of the municipal area and that they are sufficient to explain the mean development of land and rental prices.

As to the housing market by far the majority of the residential constructions which are completed during the observation period are multi-family houses; thus it follows that (1) the owner of buildings are in most cases not identical with the tenants and (2) the decision variables of single-family home-owners, like the variable for income, do not play a significant role on the demand for investments in residential construction. This observation is consistent with the statement of the land use models [3,15] that home-owners which are presumed to be wealthier than tenants settle usually on the outskirts of the standard metropolitan area and in our case outside of the municipalities. (Of course, that is not to say that there do not exist single-family homes within the municipalities mentioned above; however they were built almost all before the observation period when they were still located on the periphery of the urban area.) In addition, looking at the demand function for completed dwellings, it is to say that the supply by the residential construction industry could not be introduced into the model, because the relevant statistical data like capital stock, labour force, wages, etc. are missing. (Worthless to say that with a supply function of the residential construction industry land price, rent, and residential construction costs could be determined simultaneously.) Furthermore, no emphasis has been given to land and rental price adjustments which are caused by excess demand and which are shown in the so-called disequilibrium approach by *Fair*, *Jaffee*, and *Kelejian* [9, 10]. But as a "substitute" for the price adjustment process the attempt has been made to introduce price expectations especially into the functions of the land market. Price expectations are looked at to be important determinants of the land market where speculative gains grew out of excess demand. Figure 1 shows schematically the different markets; dotted lines indicate the relationships not considered in the model:

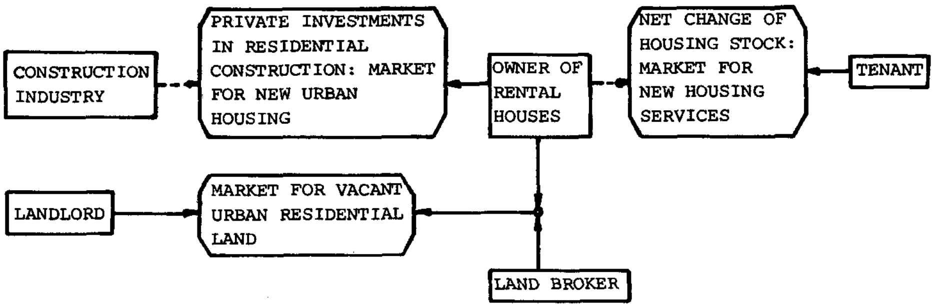


Figure 1: Contracting, land, and rental markets

## 2. The model

### *2.1. The supply of land*

It is common sense that the supply of land in square meters S depends positively on the real price of land or, what is equivalent, positively on the nominal price of land P and negatively on the price deflator C which will be specified later. The separation of the two variables means that we do not presume a priori an absence of money illusion but on the other side that we want to test it. The rising land prices during the observation period suggest that the landlord was aware of the excess demand; thus it is likely that he took into account short-term and long-term expectations on the price of land according to the circumstances. The short-term expectation is denoted by the variable E while the long-term expectation is denoted by the reserve of land L which, in the long run, reflects the scarcity of vacant land within the municipalities (see *Guth* [11]). Furthermore, it is assumed that firms (e. g. insurance companies, real estate firms) which are holding land assets are compelled to supply land when (1) liquidity assets become scant and (2) when short-term credits to fulfil current payments become tighter. One can imagine that this could happen above all during the regulation of the Swiss construction markets from 1964 to 1966. This influence of the liquidity assets is denoted by the variable A. The real estate taxes which have not been changed during the observation period, as well as the characteristics of land which are deleted according to the reasonings of our introduction are not introduced into the model. The supply function of land reads now as follows:

$$S = S(P, E, C, L, A) \tag{1}$$

with $S_P, S_L > 0$; $S_E < 0$; $S_C \lesseqgtr 0$; $S_A$ undefined,
where $S_P$, ... denote the partial derivates of S with respect to the independent variables. It will be shown that the short-term expectation of the land price E will be

represented by a construct of the nominal land price P; therefore, the price deflator C stands for both variables P and E. Moreover, this means that the coefficient of the price deflator C could be positive as well as negative.

### *2.2. The demand for land*

We think that the demand for vacant land can be derived in consequence of (1) the anticipated residential construction, (2) the short-term transactions (speculations), and (3) the long-term asset holdings. For all groups stands the price of land P which influences negatively the demand for land D. The residential construction is determined, apart from financial conditions, by anticipated demand for new housing services and this can be represented by the approved (multi-family) houses AH in the near future. Self-financing is represented by the cash flow variable CF. Financing through mortgage loans is represented by the difference of the long-term interest rate on federal bonds I and the mortgage rate M. This variable I–M can be indentified with the hypothesis on residual credits which was suggested by *Alberts* [2] and was tested by several authors (e.g. *Evans* [8], *Suits* [19], *Schiltknecht* and *Stopper* [18] for Switzerland). The empirical findings of *Arcelus* and *Meltzer* [4] namely that the "availability" of mortgage credits does not influence positively the demand for residential construction do not seem to be evident (see *Swan* [20], *Arcelus* and *Meltzer* [5]). Looking at the next two reasons which explain the demand for land, the short and long-term holding of real estate assets can be accounted for by real wealth, rate of return on land, and rates of return on opportunities. Apart from the fact that the data for wealth are missing, it is assumed that short-term transactions, i.e. speculation of market insiders of an imperfect market with high information and transaction costs, can be sufficiently explained by the anticipated rate of return on land RL when compared to the interest rate I. The stock of vacant land for residential use in a communal area with stable boundaries gets depleted when the surrounding standard metropolitan area is growing. This gives cause to the real price of land to rise (*Alonso* [3]). Therefore, it is assumed that the acceleration or the velocity of the consumer prices AC gives rise, in the long run, to shifting from more risky and inflation-bearing non-land to almost riskless land assets. The demand for land reads now:

$$D = D(P, C, AH, CF, I\text{-}M, RL, AC) \qquad (2)$$

with $D_P, D_{I\text{-}M} < 0$; $D_C, D_{AH}, D_{CF}, D_{RL}, D_{AC} > 0$,
where C denotes the price deflator.

### *2.3. The demand for gross investment in residential construction*

Recalling that we are concerned (almost only) with rental housing, the demand for new housing units NH of a particular investor can be explained by the maximization of the capital worth of all housing units -as compared to alternatives- under the constraint that the total costs of all housing units demanded be less or equal than the new owner's equity in houses plus the new mortgage loan. The most important variables which influence the capital worth of one housing unit are (1) the anticipated net rents R, (2) the anticipated discount rate I which is represented by the long-term interest rate on federal bonds, (3) the land price P, and (4) the construction costs CC. Moreover, it is expected that the value of a house at the end of the utilization period will practically be determined by the value of the site at that time; so the long-term expectation of the price of land LE will determine the capital worth as well. These variables are relative to those influencing the capital worth of the alternative investment in business construction. However, they are not introduced here because, apart from the data for the construction costs in business construction, the corresponding statistical data do not exist. The ratio of the owner's equity to the mortgage loan is determined through (1) opportunity costs and mortgage rate, and (2) through the total demand of investors for and supply by the banking system of new mortgages at actual interest rates. In analogy to the foregoing section we introduce the variable I–M for the financial conditions. The demand for new housing units reads now:

$$NH = NH(P, CC, R, I, LE, I\text{–}M) \qquad (3)$$

with $NH_P, NH_{CC}, NH_I, NH_{I\text{-}M} < 0$; $NH_R, NH_{LE} > 0$.

### *2.4. The demand for new housing services*

There exist an innumerable literature on the demand for housing services (see e.g. *Muth* [16], *DeLeeuw* [7], *Lee* [12,13,14]). In view of the poor statistical data available we do not intend to add one more hypothesis to be tested. It is assumed that the independent variables of the demand for new housing services are the first differences of those variables which determine the demand for housing services, the latter being deduced from the stock of housing units. The variables are: The permanent income per household, the income deflator C which is assumed to be the same as that for prices, the rent for one housing unit R*, the prices for other goods PS, and the number of households HH. Considering (1) that the first difference of R* can be approximately represented by the rental price for new housing units R and (2) that the *Koyck* transformation of the permanent income yields an expression which consists of the current income per household IH and of the stock of housing units lagged one period [6] we thus can write the demand for new housing services DH:

$$DH = DH(R, \triangle PS, \triangle IH, \triangle C, \triangle HH, DH_{-1}) \qquad (4)$$

with $DH_R$, $DH_{\triangle C} < 0$; $DH_{\triangle IH}$, $DH_{\triangle HH}$, $DH_{DH-1} > 0$; $DH_{\triangle PS} \lesseqgtr 0$.

The coefficient of the price variable $\triangle$ PS can be positive or negative according to the substitution effect being greater or less than the income effect.

## 3. The empirical analysis

### *3.1. The data*

The source of the significant variables is given in the appendix. The source of the variables not significant and therefore not contained in the results below are reported in detail in [6]. Unfortunately, it was not possible to separate lots for residential use from other lots, but it is presumed that the number of vacant lots for business construction was small. According to our introduction the figures for the price of land are annual averages. (The computation of a "true" price index for land, e. g. by means of the hedonic price index approach, is possible as long as the characteristics of the lots are known.) The correct variable for the gross change in the stock of housing units NH is the figure for the real investment in residential construction (see *Muth* [16]). But in order to relate the variable NH to the new housing services DH we choose as proxy for the variable NH the annually completed dwellings. These would be identical with the figures for the real investment in residential construction if we could define the new dwellings in housing equivalents. With this proxy variable we avoid to estimate the depreciation, the maintenance, and the repair expenditures of the existing housing stock. Similarly, we do not introduce the consumers' real expenditures for new rental housing (if estimable at all) but the net increase of dwellings as a proxy for the net increase of housing services DH. The correct figures of the rental price of new dwellings are not available. We use as proxy the rent index of the three cities mentioned above the sample of which is periodically enlarged.

### *3.2. Time lags*

Attempts have been made to determine the lag structure of eq. (3) by means of data not used in the model itself [6]. The hypothetical lag structure is shown in figure 2:

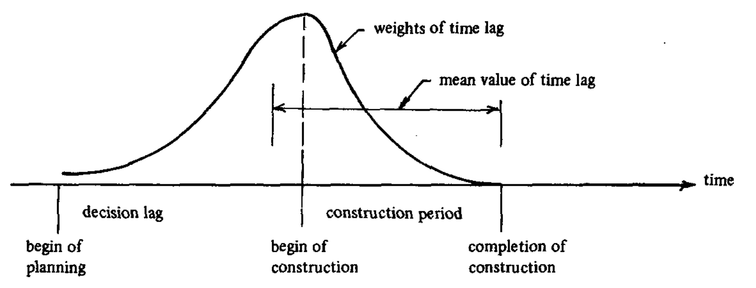


Figure 2: Lag structure for residential construction

It was possible to calculate the construction period which varies over time as shown in figure 3:

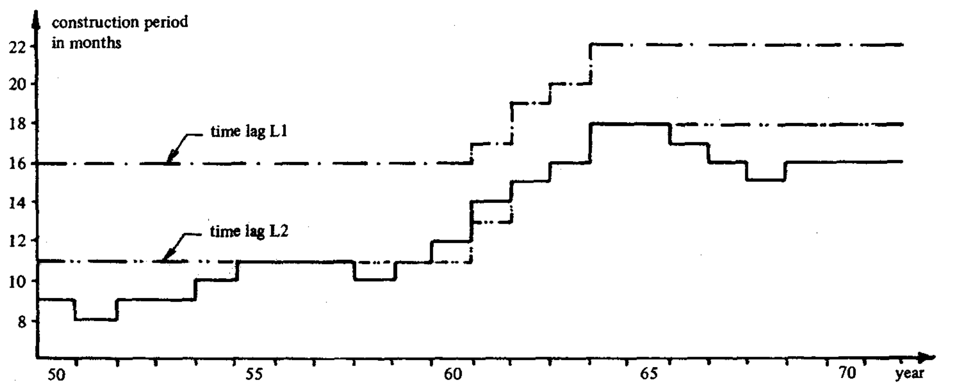


Figure 3: Construction period and average time lags L1 and L2

An economic interpretation of the time-dependent construction period is given in [6]. Instead of looking for distributed time lags with unknown weights and lengths, it was attempted to find time-dependent mean values of the distributed time lag when using the construction period as lower bound. The empirical findings suggest that the average time lag for the construction costs L1 is greater than that for the interest rates L2 as shown in figure 3. This can be explained by the fact that, in general, the financing decision will be made at a later stage than the investment decision.

### *3.3. The empirical results*

The model consists of the four structural equations (1)–(4) and of the three following identities:

$$S = D \tag{5}$$
$$P\uparrow 2 = P^2 \cdot 10^{-2} \tag{6}$$
$$NH = DH + AAD \tag{7}$$

Eq. (5) sets equal the quantities of land demanded and supplied while eq. (7) indicates the number of completed dwellings to be equal to the net increase of dwellings plus the housing alterations and demolitions (AAD). The results are presented in tables (1)–(4) where barred variables are exogenous. Abbrevations and symbols are given in the appendix. The results for eq. (1)–(3) are quite satisfactory whereas that of eq. (4) is poor. But this is not surprising when taking into account that figures for the independent variables in eq. (4) except for R,PS, and C do not exist. Unfortunately, the proxy variables for these missing figures did not work. Moreover, it should be noted that the elasticities of demand for or of supply of land with regard to long and short-term expectations L and E, approved housing projects AHL, and real land price P/C are comparable to the results for Basel as reported by *Guth* [11]. But the significantly different elasticities with regard to the land price and to the consumer price index contain evidence in favour of money illusion, i.e. suppliers of and demanders for land anticipate more than the inflation rate in such a way that suppliers will hoard vacant land while demanders want to "escape" into real estates [6].

To compute the derived reduced form eq. (6) has to be "linearized" as follows:

$$P\uparrow 2_t = P\uparrow 2_{t-1} + \overline{\triangle P\uparrow 2_t} \tag{6a}$$

The results are given in table 5 and discussed in the next section. For each endogenous variable of table 5 the first row gives the results of the SELS method, the second row those of the 2SLS method, and the third row those of the 3SLS method. It should be noted that almost all coefficients of the derived reduced form are significantly different from zero. Finally, the differences of forecasted and observed figures are less than the standard deviations of the forecasts. They are shown in table 6.

Table 1: The supply of land

| | S= | S= | S= | S= |
|---|---|---|---|---|
| 1 | −1254<br>(4109) | −1113<br>(4115) | −161.4<br>(3450) | 25.29<br>(3443) |
| $P_t$ | 89.50<br>(19.23) | 87.86<br>(19.38) | 78.38<br>(16.33) | 76.21<br>(16.43) |
| $\bar{L}_t$ | 0.3939<br>(0.07986) | 0.3908<br>(0.07999) | 0.3694<br>(0.06714) | 0.3652<br>(0.06704) |
| $\bar{E}_t$ | −113.9<br>(19.96) | −112.8<br>(20.04) | −107.1<br>(16.88) | −105.6<br>(16.89) |
| $\overline{E\uparrow 2}_t$ | 9.325<br>(2.477) | 9.316<br>(2.477) | 9.347<br>(2.090) | 9.328<br>(2.085) |
| $\overline{GC}_t$ | −729.0<br>(185.3) | −720.0<br>(185.8) | −623.8<br>(154.2) | −608.0<br>(153.9) |
| S = | 1264 | 1264 | 1108 | 1113 |
| R = | 0.9746 | 0.9745 | 0.9739 | 0.9737 |
| D.W. = | 1.90 | 1.90 | 1.90 | 1.90 |
| MV = | 9661 | 9661 | 9661 | 9661 |
| SD = | 4988 | 4988 | 4988 | 4988 |
| U = | 0.051 | 0.051 | 0.051 | 0.052 |
| Period | 1948–1971 | 1948–1971 | 1948–1971 | 1948–1971 |
| Method | SELS | 2SLS | JGLS | 3SLS |

Table 2: The demand for land

| | D = | D = | D = | D = |
|---|---|---|---|---|
| I | 10940 | 10710 | 10152 | 10060 |
| | (3754) | (3806) | (3144) | (3175) |
| $P_t$ | −93.85 | −92.14 | −84.35 | −83.17 |
| | (21.49) | (21.90) | (18.04) | (18.33) |
| $P{\uparrow}2_t$ | 20.06 | 19.64 | 17.39 | 17.05 |
| | (4.855) | (4.959) | (4.083) | (4.159) |
| $\overline{AHL}_t$ | 2.814 | 2.904 | 3.158 | 3.198 |
| | (1.456) | (1.475) | (1.219) | (1.230) |
| $\overline{(I-M)}_t$ | −23.47 | −23.28 | −18.67 | −18.13 |
| | (10.41) | (10.41) | (8.644) | (8.598) |
| $\overline{GCD64}_t$ | 842.7 | 840.6 | 739.4 | 727.7 |
| | (317.6) | (317.8) | (269.7) | (269.2) |
| S = | 1330 | 1330 | 1171 | 1177 |
| R = | 0.9718 | 0.9718 | 0.9708 | 0.9705 |
| D.W. = | 2.57 | 2.57 | 2.50 | 2.48 |
| MV = | 9661 | 9661 | 9661 | 9661 |
| SD = | 4988 | 4988 | 4988 | 4988 |
| U = | 0.053 | 0.053 | 0.054 | 0.055 |
| Period | 1948–1971 | 1948–1971 | 1948–1971 | 1948–1971 |
| Method | SELS | 2SLS | JGLS | 3SLS |

Table 3: The demand for completed dwellings

| | NH = | NH = | NH = | NH = |
|---|---|---|---|---|
| 1 | 13850 | 13930 | 11020 | 10960 |
| | (2574) | (2601) | (1812) | (1831) |
| $P_{t-2}$ | −4.001 | −3.960 | −2.988 | −3.033 |
| | (2.552) | (2.561) | (1.757) | (1.765) |
| $\overline{CCL1}_t$ | −299.2 | −300.4 | −199.0 | −197.7 |
| | (74.57) | (74.83) | (53.11) | (53.30) |
| $\overline{CCL1\uparrow 2}_t$ | 178.8 | 180.9 | 95.68 | 93.93 |
| | (63.94) | (64.91) | (44.62) | (45.28) |
| $R_t$ | 20.12 | 19.52 | 20.61 | 20.98 |
| | (9.893) | (10.35) | (6.928) | (7.258) |
| $\overline{(I-M)L2}_t$ | −10.80 | −10.87 | −7.020 | −6.983 |
| | (3.734) | (3.748) | (2.562) | (2.573) |
| $\overline{D63}_t$ | −1617 | −1618 | −1742 | −1739 |
| | (400.8) | (400.9) | (325.7) | (325.8) |
| S = | 355.8 | 355.8 | 325.9 | 326.0 |
| R = | 0.9327 | 0.9327 | 0.9198 | 0.9197 |
| D.W. = | 2.28 | 2.28 | 2.09 | 2.09 |
| MV = | 5751 | 5751 | 5751 | 5751 |
| SD = | 848.3 | 848.3 | 848.3 | 848.3 |
| U = | 0.026 | 0.026 | 0.028 | 0.028 |
| Period | 1948–1971 | 1948–1971 | 1948–1971 | 1948–1971 |
| Method | SELS | 2SLS | JGLS | 3SLS |

Table 4: The demand for net change in the stock of dwellings

| | DH = | DH = | DH = | DH = |
|---|---|---|---|---|
| 1 | 5103<br>(934.0) | 5130<br>(934.8) | 5621<br>(762.4) | 5638<br>(763.4) |
| $R_t$ | −10.75<br>(2.778) | −10.85<br>(2.782) | −11.59<br>(2.461) | −11.69<br>(2.464) |
| $DH_{t-1}$ | 0.2883<br>(0.1357) | 0.2859<br>(0.1357) | 0.2058<br>(0.1077) | 0.2055<br>(0.1078) |
| $\overline{D63}_t$ | −2335<br>(578.7) | −2335<br>(578.7) | −2344<br>(523.4) | −2345<br>(523.0) |
| S = | 566.3 | 566.3 | 521.7 | 521.8 |
| R = | 0.8509 | 0.8509 | 0.8479 | 0.8479 |
| D.W. = | 1.96 | 1.95 | 1.76 | 1.76 |
| MV = | 4659 | 4659 | 4659 | 4659 |
| SD = | 1005 | 1005 | 1005 | 1005 |
| U = | 0.054 | 0.054 | 0.055 | 0.055 |
| Period | 1948–1971 | 1948–1971 | 1948–1971 | 1948–1971 |
| Method | SELS | 2SLS | JGLS | 3SLS |

Table 6: Forecasts with standard deviations for 1971

| | S=D | NH | DH | P | P↑2 | R |
|---|---|---|---|---|---|---|
| SELS | 6501<br>(1194) | 5355<br>(489.9) | 3429<br>(489.9) | 306.8<br>(10.04) | 864.6<br>(0.0) | 281.3<br>(17.87) |
| 2SLS | 6495<br>(1194) | 5360<br>(492.9) | 3434<br>(492.9) | 306.8<br>(10.03) | 864.6<br>(0.0) | 280.9<br>(17.29) |
| 3SLS | 6181<br>(1249) | 5279<br>(507.7) | 3353<br>(507.7) | 307.0<br>(10.48) | 864.6<br>(0.0) | 278.6<br>(13.53) |
| observed value | 6924 | 4973 | 3047 | 294.04 | 864.6 | 273.1 |

Table 5: Derived reduced form with standard deviations from SELS, 2SLS, and 3SLS

| | $\overline{L}_t$ | $\overline{E}_t$ | $\overline{E\uparrow 2}_t$ | $\overline{GC}_t$ | $\overline{AHL}_t$ | $\overline{(I-M)}_t$ | $\overline{GCD64}_t$ |
|---|---|---|---|---|---|---|---|
| $S_t = D_t =$ | 0.2016 | −58.33 | 4.773 | −373.1 | 1.374 | −11.46 | 411.3 |
| | (0.03570) | (9.299) | (1.323) | (75.93) | (0.7647) | (4.802) | (146.6) |
| | 0.2020 | −58.43 | 4.786 | −373.7 | 1.359 | −11.42 | 410.5 |
| | (0.03573) | (9.296) | (1.325) | (76.03) | (0.7616) | (4.788) | (146.3) |
| | 0.1914 | −55.65 | 4.871 | −323.2 | 1.511 | −8.969 | 354.3 |
| | (0.0354) | (9.252) | (1.348) | (73.84) | (0.7695) | (4.484) | (141.8) |
| $NH_t =$ | – | – | – | – | – | – | – |
| $DH_t =$ | – | – | – | – | – | – | – |
| $P_t =$ | −0.00215 | 0.6215 | −0.05086 | 3.976 | 0.01535 | −0.1280 | 4.596 |
| | (0.00042) | (0.08683) | (0.01256) | (0.8556) | (0.00828) | (0.05323) | (1.484) |
| | −0.00214 | 0.6202 | −0.05081 | 3.967 | 0.01522 | −0.1278 | 4.596 |
| | (0.00042) | (0.08670) | (0.01255) | (0.8546) | (0.00826) | (0.05317) | (1.483) |
| | −0.00226 | 0.6579 | −0.05759 | 3.821 | 0.01933 | −0.1148 | 4.534 |
| | (0.00047) | (0.09724) | (0.01421) | (0.9266) | (0.00947) | (0.05697) | (1.642) |
| $P\uparrow 2_t =$ | – | – | – | – | – | – | – |
| $R_t =$ | – | – | – | – | – | – | – |

| | $P_{t-2}$ | $\overline{CCLI}_t$ | $\overline{CCLI\uparrow 2}_t$ | $\overline{(I-M)L2}_t$ | $\overline{D63}_t$ | $DH_{t-1}$ | $\overline{AAD}_t$ |
|---|---|---|---|---|---|---|---|
| $S_t = D_t$: | – | – | – | – | – | – | – |
| $NH_t$: | −1.393 | −104.2 | 62.25 | −3.762 | −2085 | 0.1879 | 0.6518 |
| | (0.7883) | (43.72) | (33.19) | (1.824) | (424.9) | (0.09753) | (0.1151) |
| | −1.373 | −100.4 | 59.20 | −3.616 | −2092 | 0.1909 | 0.6623 |
| | (0.7665) | (42.03) | (31.83) | (1.756) | (427.4) | (0.09816) | (0.1109) |
| | −1.059 | −68.73 | 32.03 | −2.408 | −2135 | 0.1340 | 0.6518 |
| | (0.6187) | (27.66) | (20.44) | (1.204) | (416.3) | (0.07901) | (0.09420) |
| $DH_t$: | −1.393 | −104.2 | 62.25 | −3.762 | −2085 | 0.1879 | −0.3482 |
| | (0.7883) | (43.72) | (33.19) | (1.824) | (424.9) | (0.09753) | (0.1151) |
| | −1.373 | −100.4 | 59.20 | −3.616 | −2092 | 0.1909 | −0.3377 |
| | (0.7665) | (42.03) | (31.83) | (1.756) | (427.4) | (0.09816) | (0.1109) |
| | −1.059 | −68.73 | 32.03 | −2.408 | −2135 | 0.1340 | −0.3482 |
| | (0.6187) | (27.66) | (20.44) | (1.204) | (416.3) | (0.07901) | (0.09420) |
| $P_t$: | – | – | – | – | – | – | – |
| $P\uparrow 2_t$: | – | – | – | – | – | – | – |
| $R_t$: | 0.1296 | 9.695 | −5.792 | 0.3601 | −23.25 | 0.00934 | 0.03240 |
| | (0.06909) | (3.772) | (2.946) | (0.1570) | (15.98) | (0.00471) | (0.00873) |
| | 0.1278 | 9.344 | −5.510 | 0.3365 | −22.58 | 0.00906 | 0.03143 |
| | (0.06697) | (3.617) | (2.823) | (0.1508) | (15.44) | (0.00454) | (0.00833) |
| | 0.09118 | 5.919 | −2.758 | 0.2074 | −17.97 | 0.00616 | 0.02999 |
| | (0.05106) | (2.261) | (1.730) | (0.09819) | (13.82) | (0.00346) | (0.00633) |

Table 5 continued

| | $P{\cdot}2_{t-1}$ | $\overline{\Delta P{\uparrow}2_t}$ | I |
|---|---|---|---|
| $S_t = D_t$: | 9.794 | 9.794 | 4700 |
| | (1.432) | (1.432) | (2095) |
| | 9.803 | 9.803 | 4718 |
| | (1.431) | (1.431) | (2096) |
| | 8.381 | 8.381 | 4837 |
| | (1.396) | (1.396) | (2055) |
| $NH_t$: | – | – | 8150 |
| | | | (1703) |
| | – | – | 8018 |
| | | | (1654) |
| | – | – | 7463 |
| | | | (1132) |
| $DH_t$: | – | – | 8150 |
| | | | (1703) |
| | – | – | 8018 |
| | | | (1654) |
| | – | – | 7463 |
| | | | (1132) |
| $P_t$: | 0.1094 | 0.1094 | 66.52 |
| | (0.01617) | (0.01617) | (19.97) |
| | 0.1097 | 0.1097 | 66.69 |
| | (0.01616) | (0.01616) | (19.94) |
| | 0.1073 | 0.1073 | 63.22 |
| | (0.01782) | (0.01782) | (21.94) |
| $P{\uparrow}2_t$: | 1.0 | 1.0 | – |
| $R_t$: | – | – | –283.5 |
| | | | (132.6) |
| | – | – | –271.4 |
| | | | (127.1) |
| | – | – | –158.3 |
| | | | (81.73) |

## 4. Conclusions

The purpose of this paper was to determine land and rental prices simultaneously. This is now possible with the aid of the derived reduced form. It is obvious from table 5 that the lagged price of land $P_{t-2}$ is the link between the market for land and the markets for housing. The results indicate the nominal price of land P to vary directly (1) with the long and short-term expectation of the price of land L and E, (2) with the percentage change of the consumer price index GC, and (3) with the lagged approved housing projects AHL, but to vary inversely with the difference of the interest rates I–M. When considering mean values of the variables the elasticities of the price of land with respect to the predetermined variables are as shown in table 7.

Table 7: Elasticities of land price with standard deviations from 3SLS

| L | E | AHL | (I–M) | $C_t$ (–63) | $C_t$ (64–71) |
|---|---|---|---|---|---|
| –0.61 | 0.54 | 0.22 | –0.04 | 3.00 | 4.90 |
| (0.13) | (0.12) | (0.11) | (0.02) | (0.13) | – |

The signs of the elasticities are as expected. With respect to the difference of the interest rates I–M it should be noted that this variable may be interpreted in two ways: (1) it may indicate the tightness of the mortgage market as introduced in eq. (2), thus implying the effect on land prices as a consequence of residential construction, and (2) considering the land price to be equal to the discounted land rent it follows that rising interest rates on assets other than real estates must lower the price of land (*Niehans* [17]). The figures of the elasticities may suggest that expectations on inflation had much greater influence on the price of land than real growth of business.

Furthermore, table 5 shows the rent index R to vary directly (1) with the lagged price of land P, (2) with the lagged construction costs CC, (3) with the lagged difference of interest rates (I–M), (4) with the lagged net change in the stock of dwellings DH which should be interpreted as the tenants' habit formation, and (5) with the balance of housing alterations and demolitions AAD. The elasticities of the rent index with respect to the predetermined variables are as shown in table 8.

Table 8: Elasticities of rent with standard deviations from 3SLS

| $P_{t-2}$ | CCLl | (I–M)L2 | $DH_{t-1}$ | AAD |
|---|---|---|---|---|
| 0.06 | 0.98 | 0.06 | 0.18 | 0.21 |
| (0.03) | (1.23) | (0.03) | (0.10) | (0.04) |

The signs of the elasticities are as expected. The elasticity of rent with regard to the price of land is surprisingly small when compared to that with respect to the construction costs. If the discounted rent was to be equal to the total costs of one housing unit then the elasticities of rent with respect to land price and construction costs would sum up to unity. Profits occur if this sum is greater than 1. If, in addition, it is presumed that the construction costs are one to three times as high as the land costs of one housing unit then the ratio of the two elasticities should be in the same range. Therefore, we expect the elasticity of rent with respect to the land price to lie between 0.33 and 0.98. The reason that this is not so may be seen in the poor specification of eq. (4) which is caused by the missing data. In our case the elasticities of rent with regard to the construction costs and the land price sum up approximately to unity thus determining the cost element of the rent. Above these rental costs, the other variables in table 5 determine profits, i.e. the rental price. These variables may represent an excess demand.

The results in table 5 suggest that policies, in order to reduce the land price level, (1) should increase the reserve of land through land use zoning, (2) should increase real estate taxes to avoid land hoarding, (3) should lower inflation rate to avoid the «escape» into real estates, and (4) should increase interest rates (or lower mortgage rates). Similarly, policies, in order to reduce the rent, (1) should pursue the above mentioned policies to reduce land prices except those for the interest rates, (2) should lower interest rates (or increase mortgage rates), and (3) should keep balanced housing alterations and demolitions through zoning or, possibly, direct regulation.

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## Appendix

### A1. Alphanumerical list of symbols of significant variables and sources of data

AAD — Balance of housing alterations and demolitions measured in number of dwellings.

AHL — Time lag L for approved housing projects AH. AH in number of houses.
$AHL_t = 0.334\, AHL_t + 0.666\, AHL_{t+1}$

CCL1 — Time lag L1 (see fig. 3) for the cost index of residential construction CC.

$$CCL1_t = \begin{cases} 0.667\, CC_{t-1} + 0.333\, CC_{t-2}, & t = 48\text{–}60, \; L1 = 16 \text{ months} \\ 0.583\, CC_{t-1} + 0.417\, CC_{t-2}, & t = 61, \; L1 = 17 \text{ months} \\ 0.417\, CC_{t-1} + 0.583\, CC_{t-2}, & t = 62, \; L1 = 19 \text{ months} \\ 0.333\, CC_{t-1} + 0.667\, CC_{t-2}, & t = 63, \; L1 = 20 \text{ months} \\ 0.167\, CC_{t-1} + 0.833\, CC_{t-2}, & t = 64\text{–}71, \; L1 = 22 \text{ months} \end{cases}$$

CCL1↑2 — $CCL1{\uparrow}2_t = CCL1_t^2 \cdot 10^{-2}$

D — Demand for vacant land in square meters

DH — Demand for new housing services or net change in the stock of dwellings, respectively, in number of dwellings.

D63 — Dummy variable for the exceptionally cold and long winter 1962/63.

$$D63_t = \begin{cases} 1, & t = 1963 \\ 0, & \text{otherwise} \end{cases}$$

E — Short-term expectation of the price of land. $E_t = 1.6\,P_t - 0.2\,P_{t-1} - 0.4\,P_{t-2}$.

E↑2 — $E{\uparrow}2_t = E_t^2 \cdot 10^{-2}$

GC — Growth rate of the consumer price index C. $GC_t = (C_t - C_{t-1})/(C_{t-1} \cdot 10^{-2})$

GCD64 — Growth rate of the consumer price index C with influence from 1964 onward.

$$GCD64_t = (GC_t - GC_{1964})\, D64_t, \text{ where } D64_t = \begin{cases} 0, & t = 1948\text{–}1963 \\ 1, & t = 1964\text{–}1971 \end{cases}$$

| | |
|---|---|
| (I–M) | Yield of federal bonds I minus first mortgage rate of selected state banks M. $(I-M)_t = (I_t - M_t)\,10^2$ |
| (I–M)L2 | Time lag L2 (see fig. 3) for $(I-M) \equiv X$. |

$$(I-M)L2_t = \begin{cases} 0.083\,X_t + 0.917\,X_{t-1}, & t = 48\text{–}60, \; L2 = 11 \text{ months} \\ 0.917\,X_{t-1} + 0.083\,X_{t-2}, & t = 61, \; L2 = 13 \text{ months} \\ 0.750\,X_{t-1} + 0.250\,X_{t-2}, & t = 62, \; L2 = 15 \text{ months} \\ 0.667\,X_{t-1} + 0.333\,X_{t-2}, & t = 63, \; L2 = 16 \text{ months} \\ 0.500\,X_{t-1} + 0.500\,X_{t-2}, & t = 64\text{–}71, \; L2 = 18 \text{ months} \end{cases}$$

| | |
|---|---|
| L | Proxy variable for the reserve of land measured in lot equivalents. |
| NH | Demand for new housing units or completed dwellings, respectively, in number of dwellings. |
| P | Price of land in Swiss francs per square meter. |
| P↑2 | $P{\uparrow}2_t = P_t^2 \cdot 10^{-2}$ |
| R | Rent index. |
| S | Supply of vacant land in square meters. |
| Sources: | Die Volkswirtschaft: AAD, AH, DH, NH.<br>Stat. Jahrb. Stadt Zürich, Bern und Kanton Basel-Stadt: CC, D, S, C, L, P, R.<br>Brandversicherungsanstalt des Kantons Luzern: CC.<br>Monatsbericht der Schweiz. Nationalbank: I, M. |

A2. Abbrevations for the regression analysis

| | |
|---|---|
| S | Standard deviation of the residuals corrected for degrees of freedom. |
| R | Coefficient of correlation not corrected for degrees of freedom. |
| D.W. | Durbin-Watson-statistic. |
| MV | Mean value of dependent variable (e.g. for S in table 1). |
| SD | Standard deviation of dependent variable (e.g. for S in table 1). |
| U | Theil's coefficient |
| SELS | Single-equation least squares method |
| 2SLS | Two-stage least squares method |
| JGLS | Joint generalized least squares method due to ZELLNER |
| 3SLS | Three-stage least squares method |
| Remark: | Values in parentheses are standard deviations. |

## Zusammenfassung

*Der Boden-, Wohnbau- und Wohnungsmarkt: Eine Zeitreihenuntersuchung*

In diesem Aufsatz werden der Bodenpreis und die Wohnungsmiete von drei Städten aufgrund der reduzierten Form bestimmt, die sich aus einem kurzfristigen Voraussagemodell ableitet, welches aus vier Verhaltensgleichungen und drei Identitäten besteht. Die vier Verhaltensgleichungen sind: Das Angebot an und die Nachfrage nach Boden, die Investitionsnachfrage nach Wohnbauten und schliesslich die Konsumnachfrage nach neuen Wohnungen. Die Ergebnisse für die Verhaltensgleichungen, die abgeleitete reduzierte Form und die Voraussagen werden aufgrund verschiedener Ausgleichsrechnungen bestimmt.

## Résumé

*Les marchés des terrains, de la construction et de la location de logements: étude empirique dans le temps*

Dans cet article, les prix des terrains et des loyers dans trois centres urbains sont déterminés simultanément sous une forme réduite dérivée d'un modèle prévisionnel à court terme; ce modèle étant constitué par quatre équations de comportement et trois identités. Les quatre équations de comportement sont: l'offre et la demande de terrains, la demande d'investissements en matière de bâtiments locatifs, et enfin la demande effective de nouveaux logements. Les résultats concernant les équations de comportement, la forme réduite dérivée et les prévisions sont déterminés sur la base de divers calculs de regression.

## Summary

*The Markets for Land, Housing, and Housing Services: An Empirical Study over Time*

In this paper land and rental prices of three urban centers are determined simultaneously by means of the reduced form derived from a short-term forecasting model which consists of four structural equations and three idendities. The structural equations are: The demand for and supply of land, the demand for investments in residential construction and, finally, the demand for the net change in housing services. The results for the structural equations, for the derived reduced form, and for the forecasts are obtained from various least squares methods.