

# Land Leverage and House Prices

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## Abstract

A house is a bundle of land and improvements, with the weights of the two components varying both over time and across locations. We capture the land intensity or “leverage” of a property by measuring the ratio of land to total value. This is accomplished using transactions data for single-family homes in Switzerland over the period 1978 to 2008. We show how to use hedonic models to develop time series of land prices and land leverage. Then we estimate error correction models for both house prices and land leverage. We show the importance of incorporating land leverage when assessing the determinants of house prices. House price changes are shown to be affected by changes in land leverage, real GDP per capita, growth of the population aged 30 to 49, and the term spread, while land leverage changes are a function of changes in real GDP per capita, in real construction costs, and in the term spread.

**Keywords:** land leverage, house price dynamics, land prices, error correction models

## 1. Introduction

Housing represents a large fraction of wealth in household portfolios and in national economies. A good understanding of housing dynamics and of the determinants of house price changes is thus essential. Assessment of the impacts of changes in the economy on house prices could potentially benefit by recognizing that a house is a combination of a lot and a structure (Bostic et al., 2007; Davis and Heathcote, 2007). Indeed, fundamentals affecting the prices of the two components are not the same, with changes in interest rates, income, population, and land use constraints driving land values, while building values are related primarily to construction costs. In fact, a large fraction of house price changes is typically related to land price changes rather than changes in construction costs.

If the relative value of land and structures were constant over time and locations, disentangling the two components would be of little or no importance. However, land leverage (that is, the ratio of land value to total property value) will be greater in more highly populated areas than in rural regions, and also greater at the peak than at the trough of a housing cycle. Davis and Palumbo (2008), for instance, report a land leverage of 88.5% for the San Francisco metropolitan area for 2004, but only 23.3% for Oklahoma City. Davis and Heathcote (2007) report swings in land leverage in the U.S. as a whole from less than 30% to above 45%. Moreover, there was an upward trend in

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leverage between 1975 and 2006.

It thus seems important to take into account land leverage in analyses of house price cycles. One approach to this is to consider both components of a property separately and to analyze the determining factors for each component (Davis and Heathcote, 2007). Research in this area, however, is hampered by the lack of reliable land price indexes. There are some land price indexes, such as for Japan and some Swiss regions, but these indexes do not control for the “quality” of the land; that is, they rely on mean or median prices.<sup>1</sup> There have also been some efforts to develop land value indexes for the United States. Such studies include Case (2007), Davis and Palumbo (2008), and Davis and Heathcote (2007). At a regional level, Been et al. (2009) use teardown values (prices paid for properties purchased for demolition and redevelopment) as a proxy for land values to measure land price changes in New York, following an approach suggested by Rosenthal and Helsley (1994) and extended by Dye and McMillen (2007).

This paper makes use of a rich database of house prices for Switzerland covering the period 1978 through 2008. The database contains a large number of attributes which enable us to calculate the implied land value for each sale using the depreciated cost appraisal method. Those values are in turn used to construct a hedonic index of land prices for Switzerland. We also estimate house price and land leverage hedonic models.

We use those inputs to analyze house price dynamics with error correction models. We show the importance of including an instrument for land leverage in a house price equation. Changes in real house prices appear to be driven by changes in real GDP per capita, in the term structure of interest rates (the “term spread”), in the proportion of population aged 30 to 49, and in land leverage. Changes in land leverage are shown to be affected by changes in real GDP per capita, in real construction costs, and in the term spread.

The structure of the paper is as follows. The first two sections review the literature on land leverage and discuss the theory underlying our analysis of the determinants of house prices, respectively. We then proceed to discuss our data and methods. The following section contains a discussion of our results, while a final section summarizes our conclusions.

## **2. Recent research on land leverage**

Bostic et al. (2007) introduced the term “land leverage” to refer to the ratio of land value to total property value. Although they do not use the term, Davis and Heathcote (2007) published a paper on land leverage at about the same time. Both sets of authors emphasize the relationship between land leverage and house price appreciation, a focus that was apparently motivated by a desire to explain the disparities in house price appreciation rates in different parts of the U.S. during the late 1990s and early 2000s. Bostic et al.’s empirical study of Wichita, Kansas, demonstrates that land leverage is positively associated with house price inflation in that city. These authors estimate land leverage in two ways. The first involves comparing the prices of vacant lots with the prices of the same properties after houses are constructed on them. The second method simply uses the assessed values for land and improvements determined

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<sup>1</sup> For details on the Japanese and Zurich regional indexes, see <http://www.stat.go.jp/english/data/nenkan/1431-17e.htm> and <http://www.statistik.zh.ch/bodenpreise/boe.php>, respectively.

by the local property tax assessment office. The two samples yield similar conclusions about the role of land leverage in house price inflation.

Davis and Heathcote (2007) produce quarterly constant-quality price indexes for residential land in the U.S. from 1975 through 2006. During this period, the real price of residential land nearly quadrupled, while the price of structures grew by only one-third. By 2006, land accounted for 46% of aggregate residential property value, compared with 35% in 1975. To construct their land price indexes, a benchmark market value of housing is calculated for 2000 based on the decennial census and other data. Various data sources, including Office of Federal Housing Enterprise Oversight (now the Federal Housing Finance Agency) price indexes and information about investment in new residential structures and the replacement cost of residential structures produced by the Bureau of Economic Analysis (BEA), are used to develop land price estimates for the benchmark date and to extend the series forwards and backwards from the benchmark date. A somewhat different technique is used to extend the analysis back to 1930. According to that series, land leverage was about 15% in 1930 and remained as low as about 20% in 1970.

Davis and Heathcote also show how taking land leverage into account is important when modeling house price dynamics. Their strategy is to regress real house, land, and structure prices on a set of fundamentals that includes real per capita income, the nominal three-month Treasury Bill rate, and the inflation rate. A second set of regressions adds three additional variables: population, the percentage of the population aged 35 to 54 (the primary home-buying category), and the spread between 30-year fixed mortgage rates and the three-month Treasury Bill rate. The land price regressions in particular perform better than house price regressions, and the estimates for the house price regressions appear to be a weighted average of the estimates for the land and structure price regressions.

In a related paper, Davis and Palumbo (2008) focus on 46 large metropolitan areas in the US from 1984 to 2004. For these areas, land leverage for single-family owner-occupied homes increased from an average of 32% in 1984 to 51% in 2004. In this study, the authors use RS Means construction cost data to price the housing stock in each area using property characteristics contained in the American Housing Survey (AHS) for a benchmark year. The structures are then depreciated at a rate of 1.5% per year of age. Land value is the total property value reported in the AHS less the depreciated value of the structure. The Freddie Mac Conventional Mortgage House Price Index and other data are then used to develop a time series for each metropolitan area backwards and forwards from the benchmark date.

Case (2007) estimates land leverage for residential property in the U.S. from 1975 through 2005.<sup>2</sup> Using data similar to that employed by Davis and Heathcote (2007), he produces quite different estimates of land leverage: about 14% in 1975 and 38% on 2005. For the three years for which these authors provide comparable data (1980, 1990, and 2000), Case's estimates of both total residential property values and structure values are higher and his estimates of land values are lower than those of Davis and Heathcote, meaning that his estimates of land leverage are consistently lower. Among other differences in methods, Davis and Heathcote exclude farmhouses and remove sales commissions from the BEA data, which should account for some of the

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<sup>2</sup> Malpezzi's (2007) commentary on Case's paper provides a useful short review of the empirical literature on land prices; the most remarkable study is Hoyt's analysis of land values in Chicago from 1830 to 1933 (Hoyt, 1933).

discrepancy between Case's and their results.<sup>3</sup>

Bourassa et al. (2009) incorporate a measure of land leverage in models that seek to explain how individual house prices move relative to the market as a whole in three New Zealand cities. They measure land leverage using values determined by property tax assessors. Although the focus of their paper is on the role of atypical house characteristics, they also find that houses with greater land leverage are more volatile over the course of the property cycle.

The biggest challenge in studies of land leverage is accurately measuring the ratio of land to total property value. One solution, as in Bostic et al. (2007) or Bourassa et al. (2009) is to rely on separate land and improvement values as assessed for property tax purposes. This is probably fine for their purposes, which involve the use of individual transactions data to test hypotheses about the role of land leverage. It is generally not suitable for developing indexes of land prices or land leverage over time.<sup>4</sup> As Bell et al. (2009) point out, separate land and improvement assessed values are likely to be less accurate than the combined assessments. One reason for this is that assessors typically have no incentive to make the allocation between the two components of property value accurate. In most jurisdictions, property tax rates are the same for land and improvements and property owners can challenge the total assessment, but not the individual components. Moreover, assessing land and improvement values is difficult. The sales comparison approach is hampered by the fact that there are typically few vacant land sales in developed areas. The replacement cost approach to measuring structure values depends on what are usually quite rough estimates of depreciation. Other assessment practices, such as assuming some constant ratio between land and structure values, are even less accurate. The most accurate assessments rely on hedonic regression methods that take into account spatial relationships in technically sophisticated ways.

For the United States, the recognized constant-quality national and regional house price indexes rely on repeat sales methods. These include the Federal Housing Finance Agency and S&P Case-Shiller indexes.<sup>5</sup> Because repeat sales indexes are not based on detailed property characteristics, they do not provide a good basis for constructing land or land leverage indexes. Consequently, Davis and his co-authors are forced to undertake fairly elaborate procedures in order to construct indexes for the U.S. In countries with hedonic house price indexes, the task is less convoluted. In Switzerland, for example, where hedonic house price indexes are well-developed (Bourassa et al., 2008), it is relatively easy to construct hedonic models of land prices and land leverage. The availability of details about house characteristics makes it possible to price structures using a depreciated replacement cost method. Then land values and land leverage ratios can be calculated for individual properties. Indexes can then be constructed by estimating hedonic models for land prices and land leverage that

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<sup>3</sup> Both Case (2007) and Davis and Palumbo (2008) provide estimates of land leverage for owner-occupied properties for the U.S., although Davis and Palumbo's sample is limited to 46 large metropolitan areas. Case's estimate of 33% for 1985 is quite close to Davis and Palumbo's estimate of 32% for 1984; however, Case's estimate of 38% for 2005 is much lower than Davis and Palumbo's 51% for 2004. It is likely, however, that land leverage in large cities grew at a much faster rate than in the U.S. as a whole during this period.

<sup>4</sup> However, Clapp (1990) provides a method for using assessed values to construct vacant land price indexes.

<sup>5</sup> Available at <http://www.fhfa.gov> and <http://www.standardandpoors.com>, respectively.

include time dummy variables. In this paper, we show how to do this and then use the resulting indexes in models of house price dynamics to demonstrate the importance of controlling for land leverage in modeling house price movements.

### **3. Determinants of house price changes<sup>6</sup>**

The value of a house is the sum of the structure and land values. In equilibrium, structure value will equal depreciated replacement cost; if value exceeds cost, developers will construct more houses profitably and if the reverse is true construction will cease.<sup>7</sup> The construction of new houses will depress prices on existing houses toward replacement cost, and the lack of construction, in the face of population and income growth, will eventually raise price to replacement cost. Thus we assume that structure value moves with a construction cost index.

The determinants of residential land values are more complex. The economic might of a metropolitan area or region is the primary determinant of the demand for land. This can be measured in terms of employment and income per employee or population and gross domestic product per capita. Real interest rates are also relevant because they relate expected future land rents to current values. Real mortgage interest rates are an appropriate measure because they reflect the cost of financing owner-occupied housing. The term spread may also be a relevant measure in a country such as Switzerland where all mortgage interest rates are essentially variable (so-called fixed rate mortgages are fixed for only short periods of time). The difference between short and longer term interest rates is an indicator of the direction in which financing costs are moving and hence may be more important than the current interest rate.

The demand for urban land is somewhat easier to measure than the supply. Supply is constrained by topography and land use regulations, both of which can have substantial impacts on land values and house prices (Glaeser and Gyourko, 2003; Glaeser et al., 2005; Quigley and Raphael, 2005; Saiz, 2008).<sup>8</sup> Both are also quite important in the Swiss context due to the country's mountainous terrain and relatively strict land use regulation, although whether the latter constraint changes much over time is unclear. Nevertheless, they are difficult to measure and, in the Swiss case, measures do not exist. Consequently, the land variables in our house price model focus on the demand side of the market.

## **4. Data and methods**

### **4.1 Data**

We use a large database of single-family house transactions provided by the Informations- und Ausbildungszentrum für Immobilien AG (IAZI) in Zurich. The data cover the period 1978 to 2008 and include sales price and a large number of structural and location attributes for each house sold. The data are provided to IAZI mostly by mortgage lenders.

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<sup>6</sup> This section draws from Bourassa et al. (2001) and sources cited therein.

<sup>7</sup> Gyourko and Saiz (2004) demonstrate that this also applies to homeowners' decisions to invest in improvements to their homes.

<sup>8</sup> However, Ihlanfeldt (2007) finds an inverse relationship between regulatory restrictiveness and land values in Florida.

Approximately 30 variables are used to characterize each structure and lot. These include attributes such as the year of construction, the condition of the building, the number of bathrooms, the land area, and whether there are any luxury features such as a swimming pool (a more comprehensive list of variables is provided in Bourassa et al., 2008). In addition, approximately 60 attributes are aggregated into a macro-locality index constructed for small areas within Switzerland, which captures most of the geographical variation in values. The small areas are either postal codes or smaller localities within postal codes. The locational characteristics include variables derived from tax and income statistics, population density and distribution, infrastructure statistics, and other local geographical and economic factors. These variables come from the Swiss Statistical Office, as well as various federal and cantonal tax and statistical offices.

Around 64,100 transactions of single-family houses in the whole of Switzerland were available. We excluded atypical properties for which the occupied land area was less than 5% or more than 30%. When the ratio of building volume (in cubic meters) to the living area (in square meters) was less than three or more than seven (the typical value of this ratio is four to five), the observation was likewise deleted. Further, if the price per cubic meter was less than CHF 40 the sale was deleted.<sup>9</sup> Also, properties were deleted if the calculated land leverage was not between 0% and 100%. These and other filters reduced the sample to about 56,300. Of these about 26,000 transactions involved properties aged 20 years or less since initial construction or major refurbishment. We further eliminated some house price, land price, and land leverage outliers prior to estimating the hedonic models for each of those variables.

In addition to the data from IAZI, we also use data for the Gross Domestic Product (GDP), the Consumer Price Index (CPI), and population from the Swiss Statistical Office.<sup>10</sup> With respect to population, we focus on the primary home buying age group, 30 to 49. Variable mortgage interest rates, Swiss government 10-year bond yields, and interbank 3-month rates are from the Swiss National Bank.<sup>11</sup> Finally, the construction cost index is for Zurich and is available from Baudokumentation.<sup>12</sup> The Zurich index has the longest history and using it for the entire country does not constitute a problem as, given the small size of the country, construction costs are by and large constant across regions. Figure 1 shows nominal construction cost and GDP indexes as well as the consumer price indexes, while Figure 2 depicts real mortgage interest rates and the difference between the Swiss government 10-year bond rates and interbank 3-month interest rates (the term spread) for the period under review. The rise in GDP was much more pronounced than that of construction costs during the period. In fact, construction costs did not rise in real terms. Real interest rates appear to be positively related (although imperfectly) to the term spread, suggesting that low current rates pave the way for even lower rates in the future. Figure 3 shows that, while the total population grew steadily between 1978 and 2008, the 30 to 49 home buying age group grew more rapidly than the total population until the mid-1990s and less rapidly in the 2000s. This provides a rationale for focusing on the 30 to 49 age group rather than the total population.

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<sup>9</sup> As of December 2009, CHF 1.00  $\approx$  USD 0.96.

<sup>10</sup> See <http://www.bfs.admin.ch>.

<sup>11</sup> See <http://www.snb.ch>.

<sup>12</sup> See <http://www.baudokumentation.ch>.

## 4.2 Measuring land leverage

For each house in our sample, we calculate the implicit value of the land using the depreciated cost approach. The method's economic rationale is that a house buyer would not be willing to pay more for a property than the construction cost of the structure net of any depreciation plus the value of the land. As we seek here to estimate the land value, we subtract from the house price the depreciated cost of the structure at the time of sale. The method involves calculating the construction cost of each building as of 2008 by multiplying the house's volume by a standard construction cost per cubic meter and backtracking that cost to the time of each transaction using a construction cost index. We then subtract depreciation to account for physical, functional, and economic obsolescence, and obtain land value estimates.

More formally, the procedure is the following. The price paid at time  $t$  for a single-family house ( $P_t$ ) consists of the construction cost of the building ( $C_t$ ) corrected for depreciation ( $D_t$ ) plus the land value ( $L_t$ ):

$$P_t = C_t - D_t + L_t \quad (1)$$

We calculate the construction cost as if new for each building by multiplying the volume of the building ( $V_t$ ) by the construction cost per cubic meter ( $c_t$ ):

$$C_t = (V_t \cdot c_t) \quad (2)$$

The construction costs per cubic meter are based on standard costs for Zurich as of 2008, which are then backtracked to the year of sale using the Zurich construction cost index. The standard construction cost per cubic meter as of 2008 is CHF 590 for a house of good building quality (see Table 1). A downward (upward) adjustment is made for houses of poorer (better) quality.

To calculate the appropriate depreciation at time  $t$ , we consider the economic age of the property. The age of the property ( $A_t$ ) is the minimum of the number of years since the building was first constructed and the number of years since the last complete refurbishment of the property. For example, a house constructed in 1800 with a complete refurbishment in 2000 is considered to be five years old if sold in 2005. Given the difficulties in estimating depreciation accurately for older properties, we define a restricted sample to include only those properties whose age as defined above is 20 years or less at the date of sale. The choice of 20 years is driven by the fact that the first substantial renovations of a property (such as the replacement of the kitchen or bathroom) typically occur after 20 years. We also consider the sample containing all sales.

The annual depreciation rates ( $d$ ) for various building quality levels are given in Table 2. The annual geometric depreciation rate for a building in good quality is assumed to be 1.5%. Higher (lower) depreciation rates are used for buildings of poorer (higher) quality. To test for the robustness of our results, we also use base depreciation rates of 0.5% and 2.5%. The depreciation of a property at time  $t$  is given by:

$$D_t = C_t \cdot (1 - (1 - d)^{A_t}) \quad (3)$$

Substituting equations (2) and (3) into equation (1):

$$P_t = (V_t \cdot c_t \cdot (1 - d)^{A_t}) + L_t \quad (4)$$

The land value for each transaction is computed as follows:

$$L_t = P_t - \left( V_t \cdot c_t \cdot (1-d)^A \right) \quad (5)$$

To calculate the land leverage ( $LL_t$ ) for each property, we divide the land value ( $L_t$ ) by the transaction price ( $P_t$ ). We then estimate the following regression equation:

$$LL_t = \sum_i \lambda_i \cdot Z_i + \sum_t \delta_t \cdot T_t + \varepsilon \quad (6)$$

where:  $\lambda_i$  are the coefficients of the characteristics of the land;  $Z_i$  are the characteristics of the land;  $\delta_t$  are the coefficients of the time dummy variables;  $T_t$  are the time dummy variables (1 if property sold during year  $t$  and 0 otherwise); and  $\varepsilon$  is an error term. A given transaction was included only if its land leverage was between 0% and 100%. We use equation (6) to calculate predicted land leverage for each year,  $LL_t^*$ , assuming median land characteristics.

### 4.3 Constructing land and house price indexes

No land price index exists at the national level for Switzerland. Some regional indexes exist (for Zurich and Basel Landschaft, for instance), but they are not constant quality. We opt to calculate a hedonic time dummy index given the availability of hedonic data and the ability of this method to control for quality changes. We also calculate a hedonic house price equation.

The land price index is calculated using the following regression:

$$LPSM_t = \sum_i \varphi_i \cdot Y_i + \sum_t \theta_t \cdot T_t + \varepsilon \quad (7)$$

where:  $LPSM_t$  is the land price per square meter;  $\varphi_i$  are the coefficients of the characteristics of the land;  $Y_i$  are the characteristics of the land;  $\theta_t$  are the coefficients of the time dummy variables,  $T_t$ ; and  $\varepsilon$  is an error term. The base year of the index is 2008.

For the house price index, the following regression is calculated:

$$P_t = \sum_i \tau_i \cdot W_i + \sum_t \psi_t \cdot T_t + \varepsilon \quad (8)$$

where:  $\tau_i$  are the coefficients of the characteristics of the property;  $W_i$  are the characteristics of the property;  $\psi_t$  are the coefficients of the time dummy variables,  $T_t$ ; and  $\varepsilon$  is an error term. Again, the base year of the index is 2008.

### 4.4 Modeling house prices and land leverage

We specify a long-run house price model as follows:

$$RHPI_t = \alpha_0 + \alpha_1 RCCI_t + \alpha_2 RGDP_t + \alpha_3 RIR_t + \alpha_4 TS_t + \alpha_5 POP_{3049_t} + \alpha_6 LL_t^* + \varepsilon \quad (9)$$

where:  $RHPI_t$  is the house price index derived from equation (8) and converted into real terms using the CPI;  $RCCI_t$  is the real construction cost index;  $RGDP_t$  is real GDP per capita;  $RIR_t$  is the real mortgage interest rate;  $TS_t$  is the interest rate spread between 3-month and 10-year securities (defined as the long-term rate minus the short-term rate);

$POP3049_t$  is the growth of population aged 30 to 49;  $LL_t^*$  is the predicted land leverage derived from equation (6); and  $\varepsilon$  is an error term. We use GDP rather than employment and wages or household income as a measure of demand due to inconsistencies in measurement in the other data series. A long-run land leverage model is specified using the same set of independent variables (excluding, of course, land leverage itself).

Land leverage is likely to be endogenous in a model of house prices because the factors that influence house prices also influence land and structure values and, therefore, land leverage. Consequently, we substitute an instrumental variable (IV),  $LLIV_t$ , for  $LL_t^*$  in equation (9). In the absence of other practicable alternatives, we use an IV suggested by Durbin (1954) that is defined simply as the rank order of the original variable. Thus the smallest land leverage is assigned a value of 1, the next smallest a value of 2, and so forth. This IV is discussed by Kennedy (2003) and examples of recent applications of the technique can be found in Fingleton (2000) and Heckelman (2000).

An error correction model (ECM) represents short-term changes as a function of the changes (differences) of the right-hand side variables in equation (9), adjusted by an error correction term that is defined as the deviation of previous observed levels from long-run equilibrium levels. The fitted values from equation (9) represent one way to discover the long-run equilibrium levels. The error correction term,  $EC_{t-1}$ , represents a disequilibrium in the previous time period and is expected to have a negative effect, inducing a change in house prices (or land leverage) back toward the equilibrium. Hence our short-term model is specified as follows:

$$\Delta RHPI_t = a_0 + a_1 \Delta RCCI_t + a_2 \Delta RGDP C_t + a_3 \Delta RIR_t + a_4 \Delta TS_t + a_5 \Delta POP3049_t + a_6 \Delta LLIV_t + a_7 EC_{t-1} + \varepsilon \quad (10)$$

Note that  $LLIV_t$  has been substituted for  $LL_t^*$  as for equation (9). A similar model is estimated with  $\Delta LL_t^*$  as the dependent variable (and excluding  $\Delta LLIV_t$  on the right-hand side).

There are two commonly used methods to define the error correction term: the regression method (Malpezzi, 1999; Hoesli et al., 2008) and the cointegration method (Engle and Granger, 1987; Greene, 2002). We apply both methods, although we report results only for the latter approach. The first method directly uses the error from equation (9) as an explanatory error correction term in equation (10).

The second method is popular in time series studies and uses cointegration coefficients to compute the error correction terms. In the case of house prices, the error correction term is computed as:

$$EC_{t-1} = RHPI_{t-1} + \alpha_1' RCCI_{t-1} + \alpha_2' RGDP C_{t-1} + \alpha_3' RIR_{t-1} + \alpha_4' TS_{t-1} + \alpha_5' POP3049_{t-1} + \alpha_6' LLIV_{t-1} \quad (11)$$

where  $[1, \alpha_1', \dots, \alpha_6']$  is a cointegration vector that makes  $EC_{t-1}$  a stationary process. The error correction term for the land leverage equation is computed accordingly.

## 5. Results

### 5.1 Price indexes and land leverage

The following section presents hedonic land and house price indexes as well as land leverage measures for Switzerland. The regression results for the restricted sample containing properties whose age is 20 years or younger and the full sample are reported in Tables 3 and 4, respectively. The  $R^2$  statistics are high, in particular for the land price and house price equations. To respect proprietary features of IAZI's house price model, we normalized the building characteristics so that their aggregate effect would lead to an estimated coefficient of about one.

Figure 4 contains the house and land price indexes and our measure of land leverage for 1978 through 2008 for both samples of data (the restricted sample and the sample with all transactions). The sample has only a small impact on the land price index during the 1990s and early 2000s, when the index for the full sample is consistently below that for the restricted sample. The index for the restricted sample rises by 235.2% during the period, compared to 235.4% for the full sample. There is a larger difference between the house price indexes for the two samples. The restricted sample rises by 126.9%, while the full sample rises by 148.2%. Comparison of the land price index with the house price index for the full sample suggests that, during the period under review, land prices in Switzerland rose more strongly and were more volatile than house prices. This is particularly true at the end of the 1980s when prices were rising rapidly. It is commonly accepted that during this period a bubble existed in the Swiss housing market (Hoesli et al., 1997). As a result, land leverage rose in the 1980s and then declined in the early 1990s as house and land values were declining. Land leverage then increased again from 1992 to 1994 due to declining construction costs. The land leverage during this period fluctuates from a low of 30.4% (in 1982) to a high of 48.1% (in 1989) when the restricted sample is used. Land leverage is higher when all transactions are used, especially after 2003 (from a low of 31.6% in 1982 to a high of 53.1% in 2008). These results suggest that the restricted sample is a reasonably good substitute for the full sample with respect to calculation of land (and house) price indexes, but not land leverage. As the monocentric model of urban land values would suggest, younger houses tend to have lower land-to-improvement value ratios because they are more likely to be in peripheral locations with lower land values (and higher transportation costs).

Figure 5 shows the distribution of land leverage by commune (local government) across Switzerland in 2008. This map assumes a medium quality micro location within each commune. There is a noticeable concentration of high values around several of the major cities, including Geneva and Lausanne along the edge of Lake Geneva in the west as well as in the Zurich area in the central north. There are also concentrations around Basel on the northern border west of Zurich and in the ski resort region in the eastern part of Switzerland.

### 5.2 House prices and land leverage

The stationarity of our series was tested for both levels and differences, using the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests. Both tests start with an AR(1) model, accommodating some forms of serial correlations, that is,

previous lagged differences (Greene, 2002). The lags to be included in the model depend on sample size, and the rule of thumb is  $\sqrt[3]{n-1}$ , where  $n$  is sample size. Therefore, lagged differences up to order 3 are allowed for in the model tested. The tests are conducted under the assumptions that the process has a constant mean or has a trend.

For real house prices, real construction costs, real per capita GDP, the growth of population aged 30 to 49, and land leverage (for both the restricted and the full samples), the PP tests consistently suggest that the levels are I(1) processes and the differences are stationary, under the assumption of the existence of a single mean or of a trend. Most of the tests are significant at the 5% level. The ADF tests reveal similar results, except for construction costs and GDP, for which the levels are stationary in the trend model when lagged differences are considered. For the real mortgage interest rate and for the term spread, which probably are stable over time, the results under the constant mean assumption may make more sense. Both methods tend to suggest a stationary process for levels at the 10% significance level. This means that we have a combination of stationary and I(1) processes in equations (9) and (11) which, while not ideal, is acceptable. We estimate error correction models using terms calculated with both the regression and cointegration methods, but we report results based on the cointegration method only. The two methods yield similar results, and both sets of results underscore the importance of considering land leverage when analyzing house prices.

The regression results based on the sample of houses whose age is less than or equal to 20 years at the time of sale are shown in Table 5, while Table 6 contains the results when the whole sample is used. Each table gives results for regressions of house price levels without and with land leverage as an explanatory variable (columns 1 and 2), for regressions of house price changes with land leverage and an error correction term (column 4), and for regressions of land leverage in levels (column 3) and in changes with an error correction term (column 5). These error correction models are similar to others that have been used in the literature on house price dynamics (e.g., Bourassa et al., 2001).

We first discuss the results for house prices and then turn to the results for land leverage. The results in levels show that the inclusion of land leverage is very important as it results in a substantial increase in the  $R^2$  statistic. Land leverage is also highly significant. In levels, house prices appear to be driven by real GDP per capita, the change in the population aged 30 to 49, and land leverage. The results for the restricted sample also suggest the positive impact of real construction costs. For house price changes, we focus on results for a model with land leverage given the poor results for the levels equations without land leverage. Real house price changes appear to be positively related to changes in real GDP, changes in growth (i.e., second differences) of the population aged 30 to 49, and changes in land leverage. As would be expected, the change in the term spread has a negative effect on house prices. The  $R^2$  is high (0.815) and the error correction term is highly significant. When the sample with all properties is considered, the  $R^2$  is much lower (0.560) and coefficients are less significant. The change in GDP per capita, for instance, is only significant at the 10% level. This highlights the fact that there may be fewer measurement issues with the restricted sample. The same conclusion emerges when the alternative depreciation rates (0.5% and 2.5%) are used in calculation of the land leverage series.

Focusing now on the results for land leverage, we find that the  $R^2$  statistics are lower than is the case for house price equations. Real GDP appears to be driving land

leverage in levels and is also important in explaining changes in land leverage. Land leverage changes are also negatively related to changes in real construction costs as would be expected. The change in the term spread appears to have a positive impact on land leverage changes. Caution should however be exercised as the significant impact of term structure vanishes in most instances when other depreciation rates are used. Interestingly, the results for the full sample do not appear to be of lesser quality than those for the restricted sample. In fact, they are even slightly better.

Figures 6 and 7 depict actual house price levels as well as predicted levels based on the models without and with land leverage for the restricted and full samples, respectively. The predicted values with land leverage track the actual series more closely except during some years at the beginning of the period. For the restricted sample, the correlation between changes in actual price levels and changes based on predictions from the model with land leverage is 0.82; for the model without land leverage, the correlation is 0.52. For the full sample, the correlation coefficients are 0.77 and 0.62, respectively. The difference between the correlation coefficients for the predicted changes based on the models with land leverage probably reflects the difficulty in measuring depreciation accurately for older properties.

## **6. Conclusions**

Land in locations desirable for residential use is relatively inelastically supplied. Consequently, residential land price changes over time are largely the result of changes in demand factors, such as changes in per capita GDP. In contrast, structures are relatively elastically supplied, meaning that they are influenced more by changes in supply (replacement) costs than by demand factors. Over the course of a property cycle, house price changes are largely driven by land price changes. This means that the ratio of land to property value, or land leverage, is an important factor in explaining house price movements.

It is difficult, however, to measure land prices and land leverage. We show how to measure land prices and land leverage using transactions data and hedonic models for Switzerland during the period 1978 to 2008. Structure characteristics combined with construction costs and depreciation rates are used to estimate depreciated replacement costs for single-family homes in the transactions data set. Then land values and land leverage are calculated for each property as of the transaction date. Hedonic models of house values, land values, and land leverage are then estimated, and the coefficients on the time dummies from those models are used to construct indexes. As expected, land prices are more volatile and increase at a more rapid rate than house prices. We also estimate models using only data for houses aged 20 years or less as a test of our assumptions about depreciation. We note that the house and land price indexes move similarly (although not identically) for the two samples, but that there are some differences in the two land leverage series. In particular, land leverage for the full sample becomes markedly higher than that for the restricted sample after 2004.

Finally, we estimate error correction models of both house prices and land leverage. We show the importance of including land leverage in an equation of house prices. Changes in real house prices are driven by changes in real GDP, changes in growth in the population aged between 30 and 49, and changes in land leverage. Changes in land leverage are shown to be affected by changes in real GDP per capita, changes in real construction costs, and changes in the term spread.

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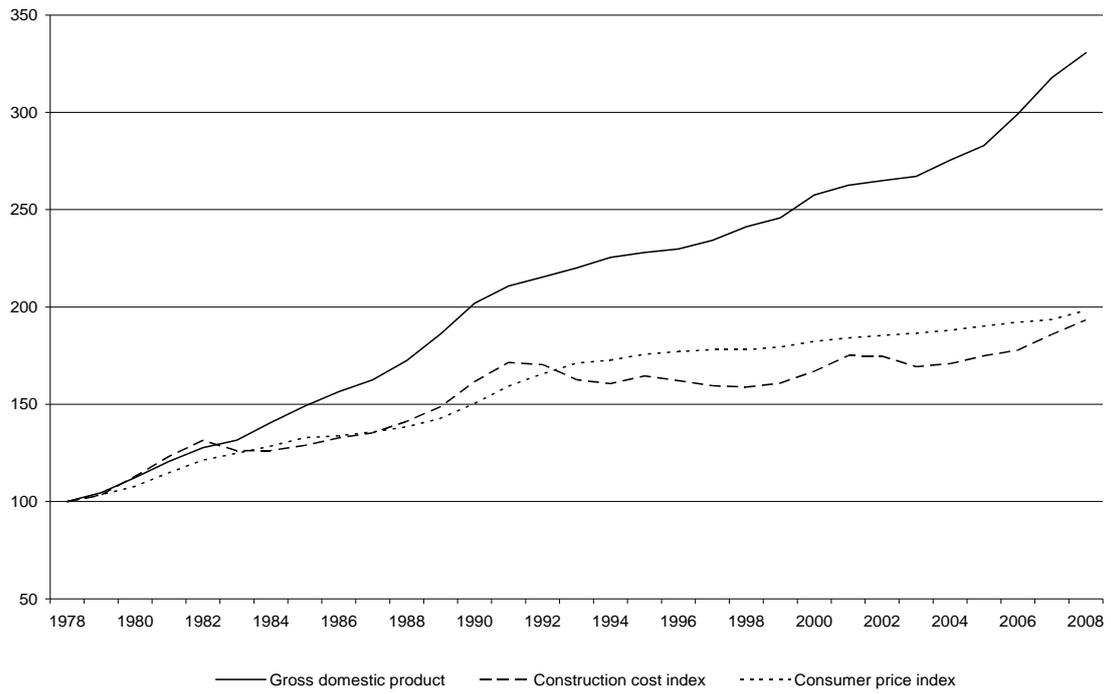
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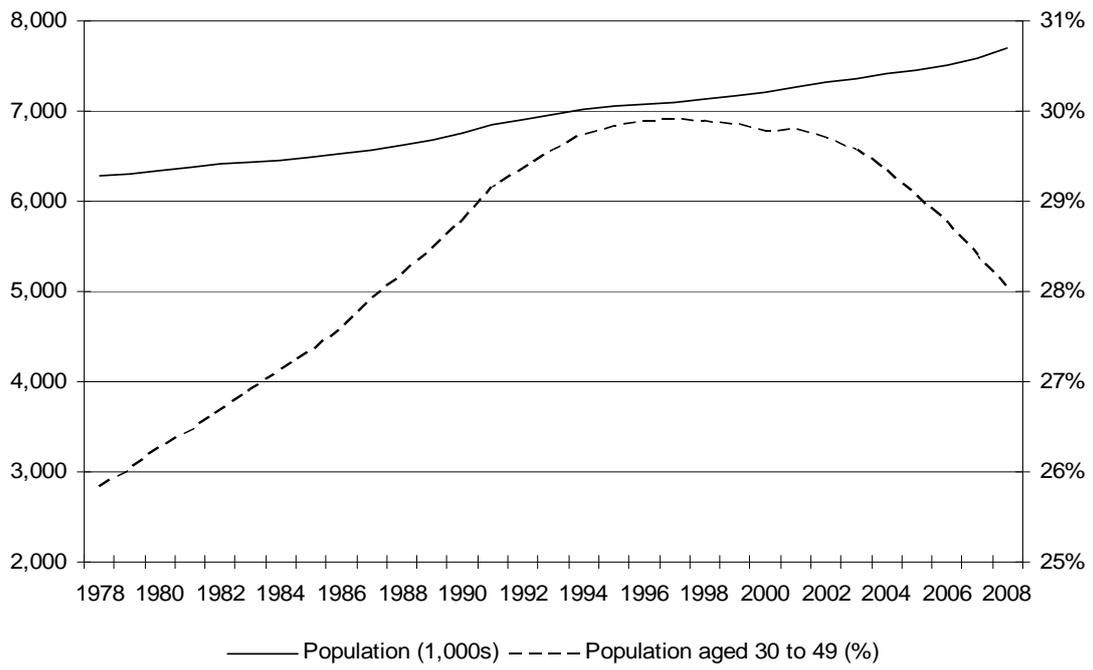
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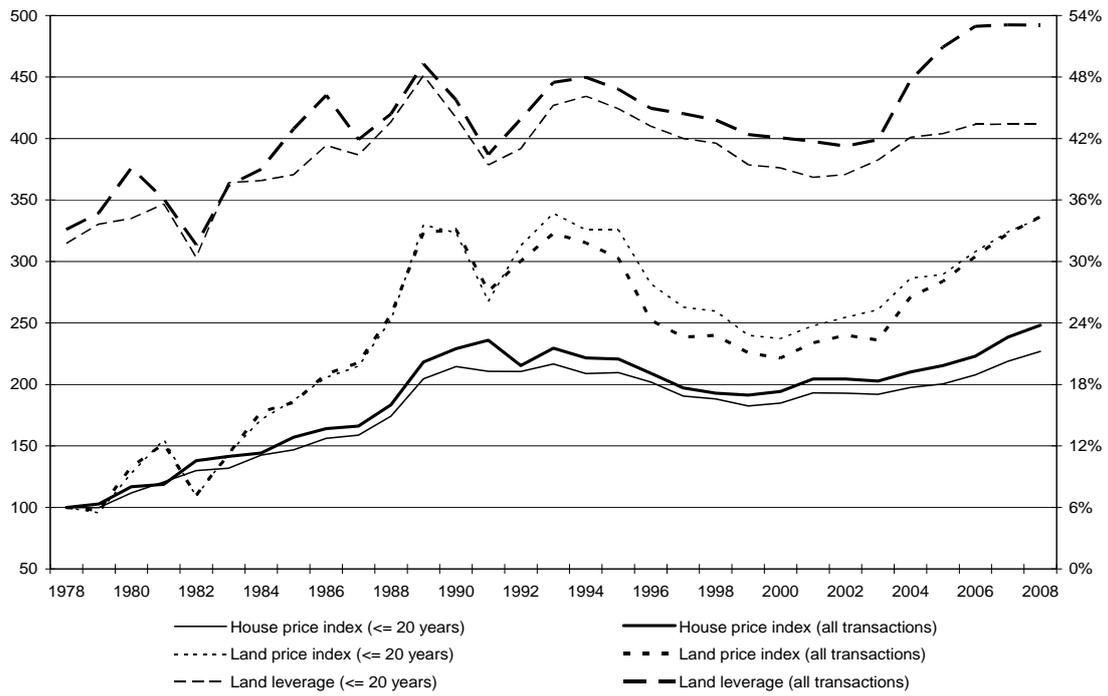
**Figure 1. Nominal construction costs, gross domestic product, and inflation, 1978-2008**



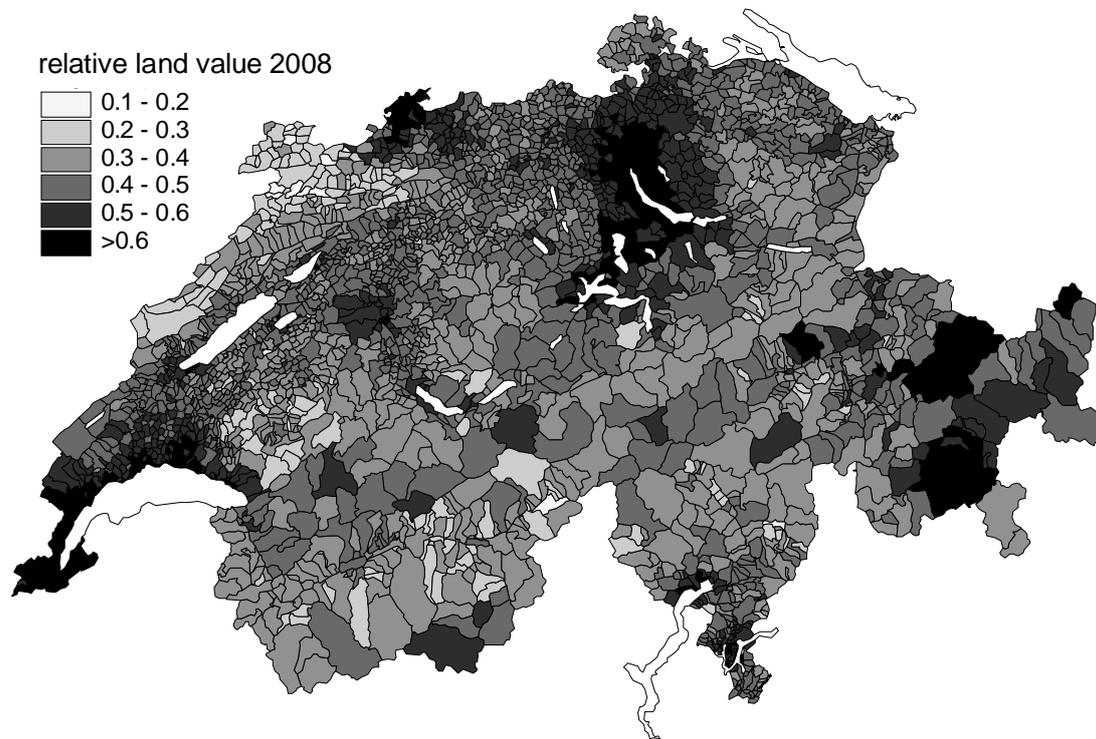
**Figure 2. Real mortgage interest rates and term spread, 1978-2008**



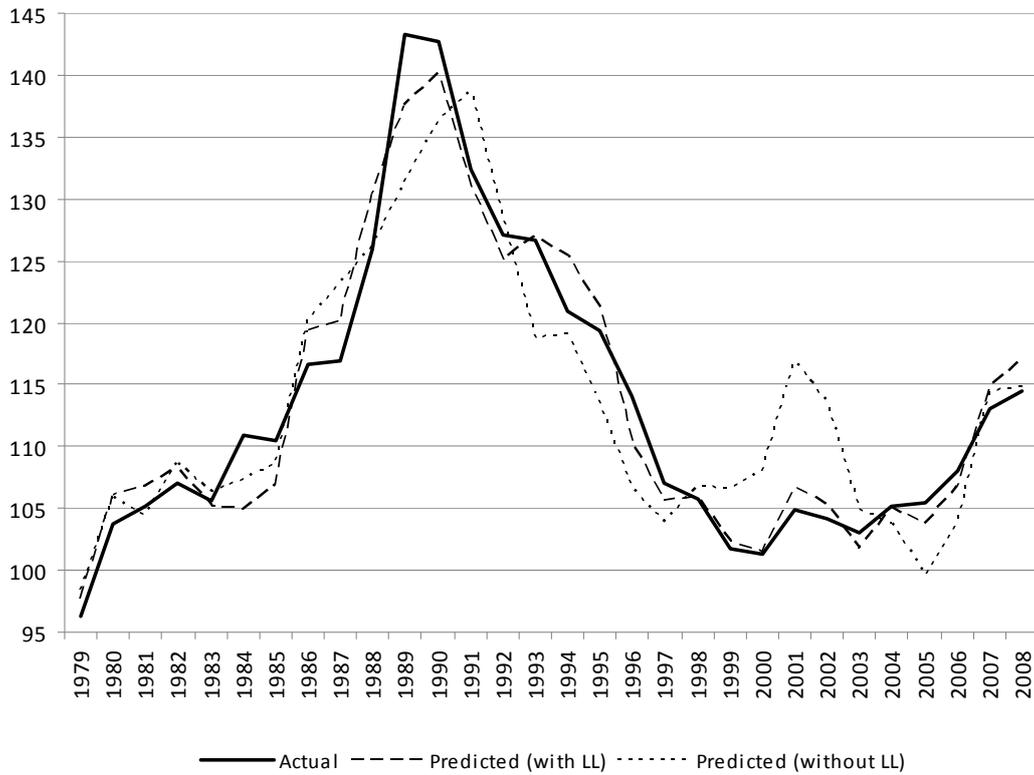
**Figure 3. Population and percentage of population aged 30 to 49, 1978-2008**



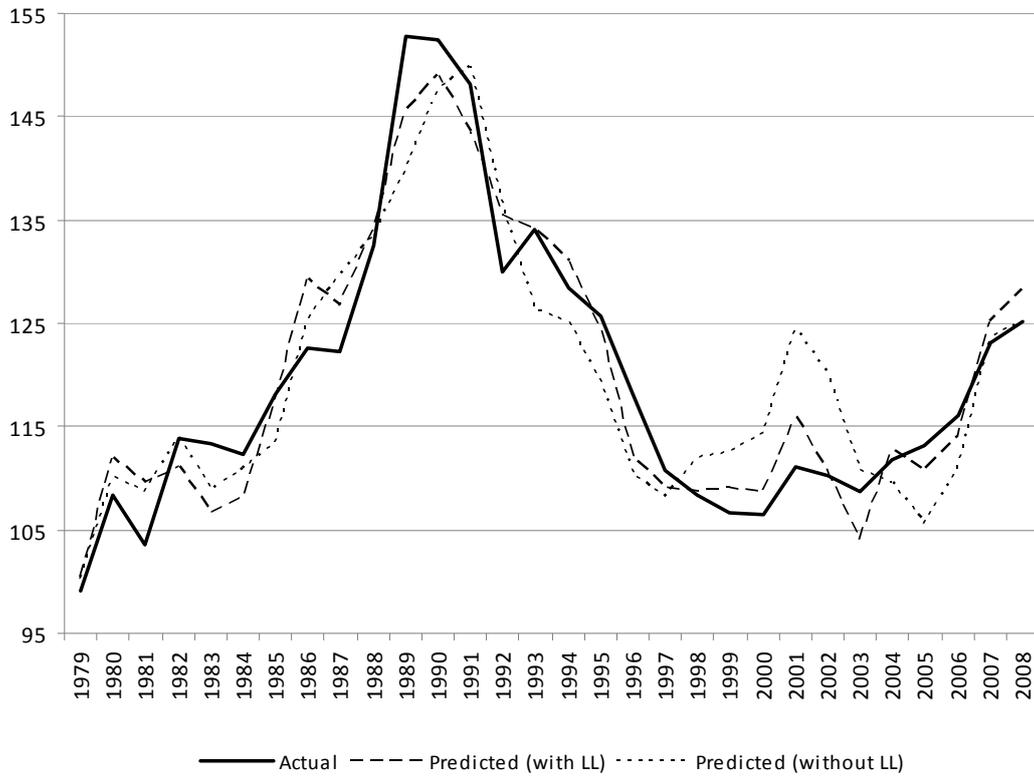
**Figure 4. Nominal house and land price indexes, and land leverage, 1978-2008**



**Figure 5. Land leverage for Swiss communes, 2008**



**Figure 6. Actual and predicted real house price levels: properties 20 years old or younger**



**Figure 7. Actual and predicted real house price levels: all properties**

**Table 1. Construction costs, 2008**

Building quality	Luxury property	Construction cost correction (%)	Construction costs (CHF per m <sup>3</sup> )
Poor	No	-10	531
Average	No	-5	561
Good	No	0	590
Very good	No	+5	620
Very good	Yes	+10	649

**Table 2. Depreciation rates (geometric)**

Condition of the building	Depreciation rate correction factor	Annual depreciation rate (%)
Poor	1.50	2.25
Average	1.25	1.88
Good	1.00	1.50
Very good	0.75	1.13

**Table 3. Hedonic regression results: properties 20 years or younger**

Variable	Land prices		House prices		Land leverage	
	Estimate		Estimate		Estimate	
Intercept	9.145	***	8.546	***	0.231	***
2007	-0.034	***	-0.036	***	0.000	
2006	-0.085	***	-0.089	***	0.000	
2005	-0.147	***	-0.124	***	-0.009	***
2004	-0.158	***	-0.138	***	-0.013	***
2003	-0.251	***	-0.167	***	-0.035	***
2002	-0.275	***	-0.162	***	-0.049	***
2001	-0.302	***	-0.161	***	-0.052	***
2000	-0.346	***	-0.205	***	-0.043	***
1999	-0.335	***	-0.218	***	-0.040	***
1998	-0.256	***	-0.187	***	-0.019	***
1997	-0.243	***	-0.174	***	-0.014	***
1996	-0.173	***	-0.116	***	-0.002	
1995	-0.029		-0.079	***	0.015	*
1994	-0.029		-0.083	***	0.027	***
1993	0.012		-0.046	***	0.018	*
1992	-0.068		-0.074	***	-0.024	*
1991	-0.225	***	-0.074	***	-0.040	***
1990	-0.036		-0.056	***	0.006	
1989	-0.016		-0.104	***	0.047	***
1988	-0.282	***	-0.264	***	0.002	
1987	-0.445	***	-0.357	***	-0.030	**
1986	-0.488	***	-0.374	***	-0.021	
1985	-0.583	***	-0.436	***	-0.049	***
1984	-0.671	***	-0.465	***	-0.055	***
1983	-0.844	***	-0.543	***	-0.057	***
1982	-1.124	***	-0.558	***	-0.130	***
1981	-0.771	***	-0.632	***	-0.078	***
1980	-0.965	***	-0.708	***	-0.092	***
1979	-1.255	***	-0.822	***	-0.098	***
1978	-1.210	***	-0.819	***	-0.117	***
Land area (ln)	-0.582	***	—		—	
Floor area ratio	0.196	***	—		—	
Micro location index	0.230	***	0.088	***	0.046	***
Macro location index	3.741	***	1.631	***	0.798	***
Building characteristics	—		1.000	***	—	
$R^2$	0.728		0.872		0.495	
Sample size	25,364		24,685		25,718	

Note: \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively.

**Table 4. Hedonic regression results: all properties**

Variable	Land prices		House prices		Land leverage	
	Estimate		Estimate		Estimate	
Intercept	8.516	***	8.829	***	0.384	***
2007	-0.042	***	-0.040	***	0.000	
2006	-0.101	***	-0.107	***	-0.001	
2005	-0.170	***	-0.142	***	-0.022	***
2004	-0.216	***	-0.167	***	-0.054	***
2003	-0.354	***	-0.202	***	-0.112	***
2002	-0.338	***	-0.194	***	-0.118	***
2001	-0.364	***	-0.194	***	-0.114	***
2000	-0.418	***	-0.245	***	-0.110	***
1999	-0.399	***	-0.260	***	-0.107	***
1998	-0.338	***	-0.252	***	-0.093	***
1997	-0.344	***	-0.230	***	-0.087	***
1996	-0.287	***	-0.171	***	-0.081	***
1995	-0.106	***	-0.118	***	-0.063	***
1994	-0.065	**	-0.113	***	-0.051	***
1993	-0.041		-0.079	***	-0.056	***
1992	-0.113	**	-0.142	***	-0.092	***
1991	-0.199	***	-0.051	***	-0.127	***
1990	-0.032		-0.080	***	-0.073	***
1989	-0.039		-0.129	***	-0.038	**
1988	-0.271	***	-0.303	***	-0.087	***
1987	-0.436	***	-0.402	***	-0.112	***
1986	-0.478	***	-0.414	***	-0.069	***
1985	-0.597	***	-0.458	***	-0.101	***
1984	-0.637	***	-0.543	***	-0.141	***
1983	-0.853	***	-0.562	***	-0.157	***
1982	-1.120	***	-0.587	***	-0.215	***
1981	-0.797	***	-0.737	***	-0.170	***
1980	-0.931	***	-0.754	***	-0.140	***
1979	-1.238	***	-0.883	***	-0.184	***
1978	-1.213	***	-0.909	***	-0.200	***
Land area (ln)	-0.494	***	—		—	
Floor area ratio	0.564	***	—		—	
Micro location index	0.224	***	0.119	***	0.026	***
Macro location index	3.662	***	1.860	***	0.832	***
Building characteristics	—		0.947	***	—	
$R^2$	0.730		0.878		0.420	
Sample size	54,480		49,618		53,213	

Note: \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively.

**Table 5. House price and land leverage regression results: properties 20 years old or younger**

Variables	Levels			Changes	
	House prices (without land leverage)	House prices (with land leverage)	Land leverage	House prices (with land leverage)	Land leverage
Intercept	-47.59	-9.42	0.08	-2.76***	-0.01*
Real construction cost index	0.65	0.76***	-0.0004	-0.35	-0.004*
Real GDP per capita (CHF 1,000s)	2.69***	0.86**	0.01***	6.60***	0.03***
Real interest rate	225.37	107.37	0.91	-52.19	-0.46
Term spread	7.68	-33.32	0.56	-74.87**	0.81***
Change in population aged 30 to 49	0.53***	0.36***	0.001	0.22**	-0.0002
Land leverage (instrument)	—	0.78***	—	0.35***	—
Error correction term	—	—	—	-0.80***	-0.03**
Sample size	30	30	30	29	29
<i>Adjusted R</i> <sup>2</sup>	0.754	0.937	0.585	0.815	0.459

Note: \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively.

**Table 6. House price and land leverage regression results: all properties**

Variables	Levels			Changes	
	House prices (without land leverage)	House prices (with land leverage)	Land leverage	House prices (with land leverage)	Land leverage
Intercept	-70.08	-13.26	-0.16	-3.06	0.006
Real construction cost index	0.63	0.51	0.0009	-0.29	-0.009***
Real GDP per capita (CHF 1,000s)	3.67***	1.84***	0.02***	4.04*	0.04***
Real interest rate	188.01	46.64	0.89	-110.35	-0.16
Term spread	-23.39	-24.35	0.21	5.36	0.85**
Change in population aged 30 to 49	0.62***	0.69***	-0.0004	0.68***	0.0006
Land leverage (instrument)	—	0.78***	—	0.52**	—
Error correction term	—	—	—	-0.30*	-0.13***
Sample size	30	30	30	29	29
<i>Adjusted R</i> <sup>2</sup>	0.776	0.901	0.620	0.560	0.491

Note: \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively.