

# What influences the growth of household debt?

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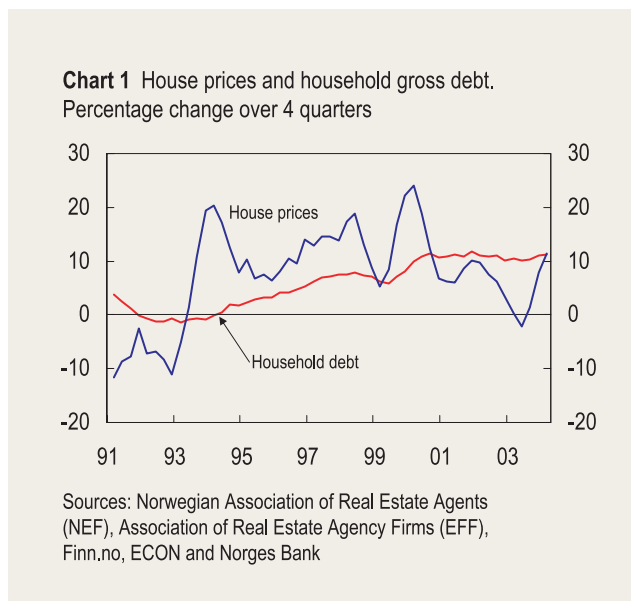
Household debt has increased by 10–11 per cent annually since 2000. In the following, the factors underlying the strong growth in debt are analysed using an empirical model. The debt growth of recent years is found to be related to developments in the housing market and to the decline in interest rates since December 2002. As a result of the sharp rise in house prices from 1998 to 2001, debt growth remained at a high level while house prices declined in the latter half of 2002 and into 2003. This reflects that only a small portion of the housing stock changes hands each year. Even if house prices level off following a rise, there will be a long period during which houses change hands at a higher price than the last time they were sold. An increase in house prices will therefore contribute to debt growth for a long time. Households may increase their debt further by raising loans to finance consumption and investment with collateral in the increased value of their dwellings. This type of borrowing has probably increased in recent years.

## Introduction

Norges Bank shall promote price stability and financial stability. Monetary policy is oriented towards achieving low and stable inflation, defined as an annual rise in consumer prices of close to 2½ per cent over time. At the same time, monetary policy can affect financial stability, since the interest rate influences private sector debt and prices for houses and securities. Strong growth in debt and in asset prices may result in financial imbalances (Borio and Lowe, 2002). Such imbalances may weaken the stability of the financial sector and result in unstable inflation and employment.

Household debt has increased by 10–11 per cent annually for the past five years. The strong growth in debt is often attributed to rising house prices and high turnover in the housing market. However, debt growth remained above or close to 10 per cent even when house prices declined in the latter half of 2002 and into 2003 (see Chart 1). This indicates that house prices influence debt with a considerable time lag. The fall in interest rates since December 2002 may explain why debt growth accelerated in the second half of 2003 and first quarter of 2004.

The purpose of this article is to shed light on factors that influence the growth of household debt. In particular, we evaluate how debt growth hinges on developments in the housing market. We estimate a model of household debt on quarterly data from 1994 Q1 to 2004 Q1. The model contains effects of house prices, the housing stock, the number of house sales, banks' lending rates, the unemployment rate, total wage income in the economy and the number of students aged 20–24 as a share of the total population. An earlier version of the model was presented in Inflation Report 2/03.



## Factors that influence household debt

Household debt is determined by demand for loans and banks' lending policy. In this section we discuss (a) the relationship between households' debt and their behaviour in the housing market, (b) demand for loans to finance consumption and investment and (c) banks' behaviour.

### *The relationship between households' debt and their behaviour in the housing market*

Household debt is largely related to the purchase of dwellings. A household buying a dwelling for the first time will normally debt-finance the purchase to a large extent. Established households will also normally increase their borrowing if they purchase a more expensive dwelling than the one they already own. Developments

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in the housing market are therefore important for debt growth. Since different types of house sales have different effects on gross debt, it is useful to classify these sales. We distinguish between purchases of new homes, first-time purchases and last-time sales of resale homes, and sales of resale homes between households that are neither entering nor leaving the housing market.

### *Purchase of new homes*

If a household raises a loan to buy a new home, it is reasonable to assume that households' total gross debt will increase correspondingly. This is because the seller is not normally another household that can use the sales sum to repay debt. For a given house price level, growth in the housing stock will therefore result in an increase in gross household debt. An increase in prices for new dwellings will further increase this debt.

### *First-time purchases and last-time sales of resale homes*

When a household enters the resale home market, another household will of necessity have to leave it. This household will free up resources. If the withdrawn equity is used for purposes other than repaying debt, total gross household debt will increase if the buyer debt-finances part of the purchase. If some of the withdrawn equity is used to repay debt, the total gross debt will increase if the increase in the buyer's debt is larger than the reduction in the seller's debt. A household that leaves the housing market will normally have entered the market a number of years previously. The residual housing loan will therefore normally be smaller than the loan of the first-time buyer. Hence total gross debt will increase when the house is sold.

What happens to debt if the price of resale homes rises? We consider a first-time buyer who entirely loan-finances the purchase of a resale home. If house prices increase, it will require a larger loan to buy the dwelling than the previous time it was sold. The price increase will therefore contribute to increasing the buyer's debt. The more house prices increase, the more resources a household that leaves the resale home market will free up. However, the household's debt is not affected by the fact that the dwelling has gained in value. The price increase will therefore result in an increase in the gross debt of households as a whole.

### *Sales between households that neither enter nor leave the resale home market*

We consider a situation in which only resale homes are sold, and none of the households either enter or leave the resale home market. Some households wish to purchase a dwelling that is larger (and more expensive) than the

one they own. In order for them to be able to do this, other households must want to buy a smaller (and less expensive) dwelling. We consider a situation with constant house prices. Households that purchase a more expensive dwelling, sell their old dwelling and finance the difference by means of a loan. Those buying a less expensive dwelling will free up resources. If the mortgage equity they withdraw is used in its entirety to repay debt, total gross debt will remain unchanged. However, debt will increase if part of the withdrawn equity is spent on consumption.

What happens to debt if house prices increase in this case? Assume that house prices increase by 10 per cent per square metre. If a given extra number of square metres are purchased, the price per dwelling will also increase by 10 per cent. The debt of those loan-financing some of the difference will increase accordingly. Those purchasing a smaller, less expensive dwelling, will free up more resources than before the price increase. Their debt will not be affected, however. The price increase will therefore result in higher gross debt for households as a whole. The less the freed up resources used to repay debt, the greater the increase in gross debt.

### *The significance of house sales*

The examples above show that total debt may increase when houses change hands. This increase in debt will be reversed as the debt is repaid. However, assume that the rate of turnover increases permanently. Then there will always be more persons than previously who have recently taken up loans. Hence the debt level will increase, also in the long term. Adaptation to the new debt level will be relatively slow. Assume that originally 10 resale homes are sold each year, and that one household raises a loan in connection with each sale. Assume further that the number of sales increases to 20 resale homes per year. The number of households that have taken up housing loans in the last 5 years will then increase from 50 to 60 the first year, and from 60 to 70 the following year. After 5 years, 100 households will have taken up housing loans. This is the new "equilibrium" level.

The channels from house prices to debt described above are dependent on dwellings being sold. If turnover increases, the effect of a higher house price will be amplified. It is likely that higher house prices move in tandem with higher turnover: increased demand for dwellings will result in a rise in prices and higher turnover if the supply of resale homes depends positively on the price, which is a reasonable assumption. In periods of low demand and low prices many will wait to sell until prices pick up. Increased turnover may also result in increased borrowing to cover agents' fees, tax on legal documents, redecorating and the purchase of furniture and white goods.

## Higher house prices will contribute to debt growth for a long time

Now assume that house prices increase (sharply) and thereafter stabilise at a new level. Some houses are sold during the price rise, and household gross debt therefore increases through the channels described above. After a while prices will stabilise, but for a long time there will be houses that are sold for a higher price than the last time they changed hands. In principle, the rise in prices will contribute to debt growth until the entire housing stock has been sold at the new price level. About 4 per cent of the housing stock changed hands in 2001.<sup>2</sup> If 4 per cent of the housing stock is sold each year, a price rise today could theoretically contribute to growth in debt for 25 years.

## Demand for loans to finance consumption and other investments

Some households take up loans for redecorating and investment in financial assets, to purchase cars and other consumer durables and to purchase houses, cabins and apartments that are not used daily. This demand for loans depends largely on interest expenses, housing wealth, households' income and their assessment of their future capacity to pay off their debt.

Increased income and/or lower interest expenses enable households to service higher debt. Moreover, it will be relatively more attractive to borrow than to save if interest rates fall. Demand for loans will therefore increase. Households' assessment of their future capacity to pay is probably sensitive to changes in the labour market. Higher unemployment may lead to expectations of lower wage growth and greater uncertainty concerning future income. This will curb demand for loans.

A rise in house prices may result in increased demand for loans to fund consumption and other investments via a wealth effect and via a price effect.<sup>3</sup> Higher house prices result in increased housing wealth. The expected final wealth (inheritance) will also increase if the price increase is expected to persist. Some households may wish to withdraw some of this gain in the form of increased consumption. They will then either reduce their financial wealth or increase their demand for loans. The price increase may also contribute to reducing the borrowing rate facing households (the price effect). This reflects that (i) housing loans are secured by collateral in the dwelling and (ii) other types of loan have weaker or no collateral – and therefore a higher interest rate. The collateral value of houses increases if banks or other providers of credit expect the price increase to persist. This will increase households' possibility of raising loans secured by collateral in their dwelling, at lower

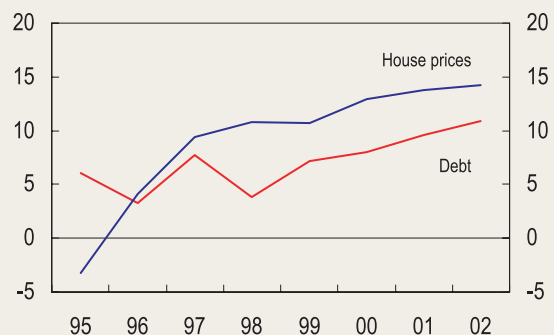
interest rates than rates on other loans. The higher collateral value may also result in a lower interest rate on housing loans.

Since house prices have fallen in periods during the last 20 years, a price increase will not necessarily be perceived as permanent. Banks and households will probably "wait and see" before making any change in their behaviour. This implies that debt is influenced with a time lag when house prices change.

Empirical studies have produced evidence that house prices affect private consumption in Norway.<sup>4</sup> Persons of a mature age – with low residual housing loans – may have a particular tendency to raise loans to fund consumption and other investments with collateral in (increased) property values. The debt of mature age groups has increased substantially in recent years. Chart 2 indicates that the increase in debt is related to the preceding rise in house prices. The increase in debt may also reflect a shift in household preferences: it may have become more accepted to leave mortgaged dwellings to the next generation. The rise in house prices may have contributed to this by resulting in increased (expected) final wealth for mature households. The increase in housing wealth has reduced the need to save financial wealth for the next generation.

Most students take up student loans. In addition, persons with higher education normally take up higher housing loans than those without higher education (all else being equal). There is therefore reason to believe that gross debt will increase with the share of students in the population. An increase in the share of students will therefore contribute to debt growth for a long period. First, most student loans increase throughout the study period. Second, for a given total population, there will be more new students each year than was the case previously. As

**Chart 2** Debt of persons aged 55-66 and house prices projected 2 years ahead. Average growth over 3 years. Per cent



Sources: Norwegian Association of Real Estate Agents (NEF), Association of Real Estate Agency Firms (EFF), Finn.no, ECON, Statistics Norway and Norges Bank

<sup>2</sup> The estimate is based on the sales figures used below and data on the number of occupied homes from the 2001 population and housing census.

<sup>3</sup> The significance of these relationships has been discussed extensively in recent years. See for example Debelle (2004) and articles in *The Economist*.

<sup>4</sup> See Brodin and Nymoene (1992), Eika and Nymoene (1992), Harildstad and Nymoene (1993), Brubakk (1994), Frøiland (1999), Eitrheim, Jansen and Nymoene (2002), Boug, Dyvi, Johansen and Naug (2002, Chapter 5.3) and Erlandsen (2003).

a result, the share of persons with higher education (and student loans) will increase over a period of years. The contribution to debt growth will taper off when this share stabilises (cf. similar reasoning in the section about changed sales above).

### *Banks' behaviour*

Households raise a large proportion of their debt in private banks. Banks' lending policy may therefore be important to debt growth. This policy depends on banks' profitability, on customers' (expected) capacity to pay and on the value of their collateral.<sup>5</sup> Banks may become more reluctant to extend loans if their profitability deteriorates, if the value of the collateral decreases or if customers (are expected to) become less able to pay off their debt. Some customers may then be rationed or be offered such poor borrowing terms that they do not wish to take up loans (any longer). The supply of loans will therefore depend positively on households' housing wealth and income, including interest income and expenses. As noted above, increased unemployment will give rise to expectations of lower wage growth and increased uncertainty about households' future payment capacity. This will probably reduce the supply of credit to households.<sup>6</sup> A rise in defaults by both enterprises and households may also cause banks to be more cautious about extending loans to households.

This discussion indicates that the supply of credit will have an independent effect on the demand for dwellings. If this is the case, house prices and household debt should in principle be modelled simultaneously. However, we do not find significant effects of household debt in the house price model presented in Financial Stability 1/04;<sup>7</sup> banks' behaviour is captured by other variables in the model (house price, interest rate, unemployment, housing stock and wage income). The debt equation below is therefore estimated using the method of ordinary least squares. We test for effects of defaults, however.

## A model of household debt

We model households' domestic gross debt as measured by the C2 credit indicator. This debt consists of loans from domestic banks, mortgage companies, finance companies, government lending institutions, life and

non-life insurance companies, private and municipal pension funds, the Government Public Service Pension Fund and Norges Bank. Household bond and short-term paper debt raised in the domestic market is also included. The C2 figures for household debt extend back to December 1995. We have extended the time series backwards with growth rates for household gross debt as measured in the RIMINI database (RIMINI is a macro-economic model developed in Norges Bank). This debt consists of tax debt, foreign debt, debt to non-financial enterprises and debt included in C2 less bond and short-term paper debt.

We started with a flexible dynamic model that contained effects of house prices, the housing stock, the number of house sales, banks' lending rate after tax<sup>8</sup>, the unemployment rate, total wage income<sup>9</sup> in the economy, the number of defaulted loans (for both households and the public in general) and the number of students aged 20–24 as a share of the total population. In addition we included a stochastic trend<sup>10</sup> to capture effects of changed preferences among mature age groups in the estimation period. We then simplified the general model by placing restrictions on the coefficients that were not rejected by the data and that simplified the interpretation of the dynamics.

The number of defaulted loans has a significant negative effect if we start the estimation in the second quarter of 1993 or earlier (we have default figures for the period 1990 Q3 to 2003 Q4). If we instead start the estimation in 1994 Q1 or later, the default variables have an insignificant positive effect. These results indicate that (i) substantial defaulting, among both enterprises and households, contributed to banks' limiting credit growth in the period immediately after the banking crisis at the beginning of the 1990s and (ii) developments in defaulting have not had any major effect on debt growth since 1993, even though the number of defaulted loans has increased in recent years. We therefore choose to start the estimation in 1994 Q1.<sup>11</sup>

We simplified the trend to a constant without the fit being significantly weakened. In other words, we did not find significant effects due to changed preferences (in the estimation period) beyond those that are captured by variables in the model.<sup>12</sup> The rise in house prices may have changed the preferences of households of mature age in recent years (see section 2).

The preferred model is specified in a separate box.

<sup>5</sup> See Stiglitz (1992, sections 6.2–6.3) for a theoretical discussion.

<sup>6</sup> Frøyland and Larsen (2002) estimate a model for banks' losses on loans to households. They find that losses increase with debt, the interest rate level and the unemployment rate; increased income and housing wealth result in lower losses.

<sup>7</sup> The model has been estimated on data from 1990 Q2 to 2004 Q1. Household debt has a significant effect in models of Norwegian house prices that are estimated using data from the 1980s and 1990s (see Eitheim (1993) and Boug et al. (2002, Chapter 5.5)).

<sup>8</sup> We also tried to include various measures of the real after-tax interest rate. Equations with constant inflation expectations fitted best. We are therefore omitting inflation expectations from the model (the effects of constant inflation expectations are captured by the intercept).

<sup>9</sup> Tax-motivated fluctuations in share dividends have had a major effect on the measured developments in household income in recent years. We therefore choose to use wage income instead of disposable income as an explanatory variable.

<sup>10</sup> A stochastic trend is more flexible than a linear (deterministic) trend, and can capture effects of excluded fluctuating variables. The formulation is described in Koopman et al. (2000).

<sup>11</sup> We could instead have estimated a model in which the parameters vary from one "regime" to the next. Aron and Muellbauer (2000) estimate such a model for debt growth in South African households.

<sup>12</sup> The same conclusion is reached if we test for such effects using dummy variables.

## A model of household debt

$$\begin{aligned} \Delta debt_t = & 1.00 \Delta housingstock_t - 0.29 \Delta (debt - housingstock)_{t-1} - 0.29 \Delta INTEREST_t \\ & \quad (2.64) \qquad \qquad \qquad (5.24) \\ & + 0.02 \Delta turnover_{t-2} + 0.01 (\Delta_4 income_t + \Delta houseprice_t) - 0.03 \Delta unemployment_t \\ & \quad (3.01) \qquad \qquad \qquad (1.52) \qquad \qquad \qquad (3.89) \\ & - 0.07 [debt - houseprice - housingstock + 1.70 INTEREST - 0.17 turnover - 0.64 studentshare]_{t-1} \\ & \quad (7.41) \qquad \qquad \qquad (3.16) \qquad \qquad \qquad (1.36) \qquad \qquad \qquad (4.95) \end{aligned}$$

Estimation period: 1994 Q1 – 2004 Q1.

$\sigma = 0.0019$ ,  $DW = 2.20$ .

Estimation method: Ordinary least squares

Absolute  $t$  values are given in brackets under the estimates.

$\Delta$  is a difference operator:  $\Delta X_t = (X_t - X_{t-1})$ ,  $\Delta_4 X_t = (X_t - X_{t-4})$

The variables and test statistics are defined as (small letters indicate that variables are measured on a logarithmic scale):

<i>debt</i>	= Households' domestic gross debt (Source: Norges Bank, NB)
<i>housingstock</i>	= Value of housing stock measured at constant prices (Source: Statistics Norway, SN)
<i>INTEREST</i>	= Banks' average lending rate. (Source: NB)
<i>turnover</i>	= Number of house sales (Sources: SN and Norwegian Federation of Cooperative Housing Associations)
<i>income</i>	= Total wage income in the economy. Depends on the wage level and employment (Source: SN)
<i>houseprice</i>	= Price index for resale homes (price per m <sup>2</sup> ) (Sources: NEF, EFF, FINN.no, ECON and NB)
<i>unemployment</i>	= Unemployment rate (Source: The Directorate of Labour)
<i>studentshare</i>	= No. of students aged 20–24 years as a share of the population. Average for 5 quarters (Source: SN)
$\sigma$	= Standard deviation of regression residuals
<i>DW</i>	= Durbin Watson test statistic

The expression in brackets measures the deviation between debt in the previous quarter and an estimated long-term relationship between debt, house prices, the housing stock, banks' lending rates, house sales and the share of students. The model also contains an intercept and effects of seasonal variation. It has stable coefficients and passes standard tests for autocorrelation, normality and heteroscedasticity. Debt, the interest rate and the housing stock are measured at the end of each quarter. The other variables are measured as a quarterly average. The values of *INTEREST* and *income* for 2004 Q1 are based on estimates from *Inflation Report* 1/04.

The model is an error correction model for the logarithm of household gross debt. It contains effects of house prices, the housing stock, turnover, nominal interest rates<sup>13</sup>, unemployment, wage income and the student share as discussed above. Chart 3 shows that the model fits well.

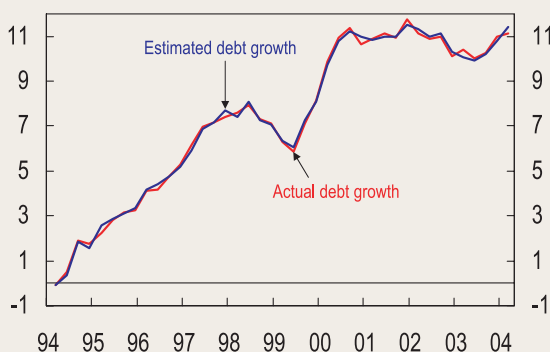
### How is debt affected by shifts in the explanatory factors?

The model implies that household gross debt will increase by 1¾ per cent through the first year and by 10 per cent in the long term if house prices increase permanently by 10 per cent and the other factors remain unchanged. The results confirm that higher house prices will contribute to debt growth for a long time (see Chart 4). About half of the effect will have materialised after 3½ years, and 90 per cent after 10 years. After 25 years, household debt will have increased by 9¾ per cent.

A 10 per cent increase in the housing stock will also increase debt by 10 per cent in the long term, for a given house price. In keeping with the discussion above, we have stipulated that the long-term effect of a change in the housing stock will be achieved already in the first quarter. This restriction is not rejected by the data. Developments in the housing stock will also affect debt by influencing house prices. The house price model in Financial Stability 1/04 implies that house prices will fall by 17 per cent in the long term if the housing stock increases by 10 per cent. An increased housing stock will thus result in lower debt in the long term if we take into account that house prices are also affected.

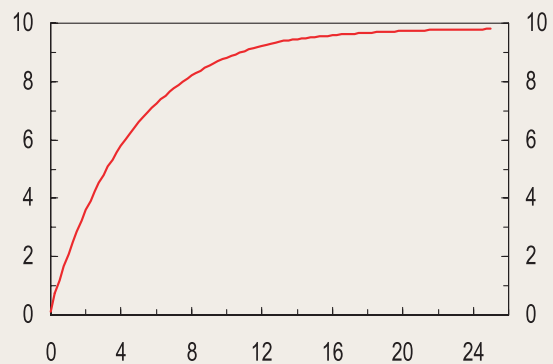
According to the model, debt will increase by 17 per cent in the long term if turnover increases by 10 per cent (turnover increased by 12½ per cent from 2000 to 2003). Adaptation is slow: debt will only have increased by 7 per cent after 2 years and by 10 per cent after 4 years. This slow adaptation is consistent with the discussion in section 2.

**Chart 3** Actual and estimated household gross debt. Percentage change over 4 quarters



Source: Norges Bank

**Chart 4** Change in gross debt when house prices increase permanently by 10 per cent. Percentage change over time (0-25 years)



Source: Norges Bank

The model implies that debt will decline by ½ per cent during the first year and by 1¾ per cent in the long term if banks' lending rates increase by one percentage point and the other variables remain constant. An increase in the interest rate will also affect debt growth via a number of the other variables in the model. The house price equation in Financial Stability 1/04 implies that house prices will fall by 3¾ per cent if the interest rate rises by 1 percentage point and other explanatory factors for house prices remain unchanged.

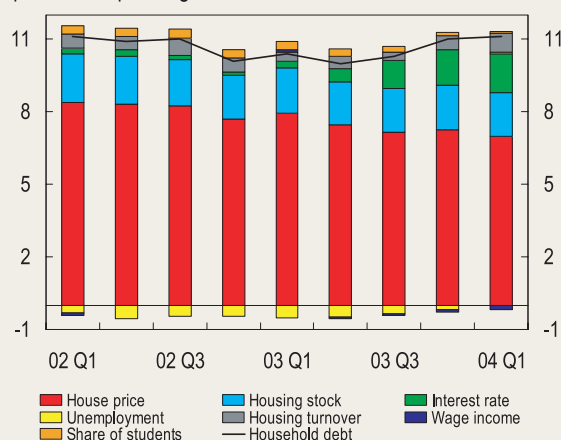
The analysis indicates that debt will only fall by ½ per cent in the first two years if the unemployment rate increases from 4 to 5 per cent and the other variables remain constant; the long-term effect is equal to zero. An increase in wage income also has a limited effect on debt for a given house price. Debt growth is nevertheless sensitive to changes in unemployment and wage income, since these variables have a strong influence on house prices (according to the house price equation in Financial Stability 1/04). Household debt increases by 6 per cent if the share of students increases by 10 per cent. Half of the effect will have materialised after 4 years (cf. discussion in section 2).

### Decomposition of debt growth

The early 1990s were characterised by a banking crisis, high interest rates and high unemployment. The banks' problems probably contributed to limiting debt growth (see above). Unemployment and interest rates have fallen substantially since the early 1990s, resulting in a sharp rise in house prices (see Chart 1 and the house price equation in Financial Stability 1/04). We find that an increase in house prices will contribute to debt growth for a long period. The growth in debt over the last 10–15 years can therefore be partially viewed as an adjustment from a situation with a banking crisis, high interest rates and high unemployment, to a new situation with relatively low interest rates, relatively low

<sup>13</sup> We exclude the tax deduction for interest on debt, as this is constant throughout the estimation period.

**Chart 5** Household debt and estimated contributions from explanatory factors in the model. Contribution in percentage points to 4-quarter growth



Source: Norges Bank

unemployment and a smoothly functioning credit market.

Chart 5 decomposes the debt growth of the last two years (up to 2003 Q1) in accordance with the estimated model (see appendix for an account of the method of decomposition). The calculations show that the rise in house prices pushed up four-quarter growth by about 8 percentage points in the period 2002 Q1 to 2003 Q1. This illustrates that a change in house prices affects debt growth with a considerable time lag: although house prices fell during the last part of 2002 and into 2003, debt growth was maintained at a high level by the sharp rise in house prices from 1998 to 2001. The contribution from house prices has declined in the past year as a result of the sluggish price developments in the last part of 2002 and first part of 2003. The increase in house sales contributed positively to debt growth in the period 2002 Q1 to 2004 Q1.

Developments in interest rate, unemployment, wage income and the housing stock influence debt growth directly and by affecting house prices. Chart 5 shows that new construction has pushed up four-quarter growth by 2 percentage points in the last 2 years, all else being equal. However, new construction may have curbed the rise in house prices by 3–4 percentage points in the same period (see box on house prices in Financial Stability 1/04). The reduction in interest rates since December 2002 has pushed up debt growth by ½–1½ percentage points this past year for given house prices. Moreover, the decline in interest rates has contributed to boosting the rise in house prices. These factors in isolation will result in higher debt growth in the years ahead. Increased unemployment in 2002 and 2003 pushed down debt growth by ¼–½ percentage point in the period 2002 Q1 to 2003 Q4. Developments in unemployment made a positive contribution to debt growth in 2004 Q1. However, the rise in unemployment in 2002

and 2003 dampened the rise in house prices. Developments in wage income have primarily influenced debt growth by affecting house prices.

## Conclusion

The growth of debt in Norwegian households has been higher than income growth in recent years. The high debt growth is found to be related to developments in the housing market and to the decline in interest rates since December 2002. As a result of the sharp rise in house prices from 1998 to 2001, debt growth remained at a high level while house prices declined in the latter half of 2002 and into 2003. This reflects that only a small portion of the housing stock changes hands each year. Even if prices stabilise following a rise, there will be a long period during which houses change hands at a higher price than the last time they were sold. An increase in house prices will therefore contribute to debt growth for a long time. Household debt may increase further because higher house prices may result in higher final wealth and better borrowing conditions for many households. These households will then have a greater incentive to raise loans secured by collateral in their dwelling to finance consumption and investment. This type of borrowing has probably increased in recent years.

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## Appendix: A method for decomposing debt growth

We consider the following simplification of the model in the article:

$$(1) \quad y_t = \alpha x_t + \gamma z_t + \beta y_{t-1} + \varepsilon_t, \quad |\beta| < 1.$$

Here  $y$  is the logarithm of the debt level;  $x$  and  $z$  are explanatory variables;  $\alpha$ ,  $\gamma$  and  $\beta$  are parameters and  $\varepsilon$  is an error term. The subscripts indicate the period. By backdating the variables and the error term in (1) by one period we get:

$$(2) \quad y_{t-1} = \alpha x_{t-1} + \gamma z_{t-1} + \beta y_{t-2} + \varepsilon_{t-1}.$$

Equation (2) inserted in equation (1) gives:

$$(3) \quad y_t = \alpha x_t + \alpha\beta x_{t-1} + \gamma z_t + \gamma\beta z_{t-1} + \beta^2 y_{t-2} + \beta\varepsilon_{t-1} + \varepsilon_t.$$

We get the following expression by continuing the insertion backwards:

$$(4) \quad y_t = \alpha \sum_{i=0}^{\infty} \beta^i x_{t-i} + \gamma \sum_{i=0}^{\infty} \beta^i z_{t-i} + \sum_{i=0}^{\infty} \beta^i \varepsilon_{t-i},$$

where:

$$\alpha \sum_{i=0}^{\infty} \beta^i x_{t-i} = \text{total contribution from } x \text{ to } y_t \text{ (contributions from } x_t, x_{t-1}, \dots, x_{t-\infty})$$

$$\gamma \sum_{i=0}^{\infty} \beta^i z_{t-i} = \text{total contribution from } z \text{ to } y_t \text{ (contributions from } z_t, z_{t-1}, \dots, z_{t-\infty})$$

$$\sum_{i=0}^{\infty} \beta^i \varepsilon_{t-i} = \text{total contribution from other (omitted) explanatory factors to } y_t$$

Since  $|\beta| < 1$ , the contributions from  $x_{t-i}$ ,  $z_{t-i}$  and  $\varepsilon_{t-i}$  to  $y_t$  will decrease gradually when  $i \rightarrow \infty$ .

We use estimates for  $(\alpha, \gamma, \beta)$  and values of  $(x_t, x_{t-1}, \dots, x_{t-80})$  and  $(z_t, z_{t-1}, \dots, z_{t-80})$  to calculate the contributions from  $x$  and  $z$  to  $y_t$ . Then we decompose debt growth over four quarters by transforming the estimated contributions.