# How vulnerable are financial institutions to macroeconomic changes? An analysis based on stress testing

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**Macroeconomic changes have been an important reason why financial institutions have experienced losses on loans to households and enterprises. This article contains an analysis of financial institutions' vulnerability in two stress test scenarios using a new analytical framework. The results indicate that a fall in property prices, higher interest expenses and stronger wage growth will lead to higher losses on loans to enterprises and households. The analytical methods used here are still being developed, and the results must be interpreted with caution.**



## 1 Introduction

Norges Bank has the objectives of price stability and financial stability. Financial stability implies that the financial system has good "shock absorbers" to reduce the risk of problems in one financial institution spreading to others. At worst, financial instability may lead to systemic and banking crises. The weaker the institution is financially, the greater the possibility of negative economic changes resulting in a financial crisis. Norges Bank closely monitors factors that affect financial stability. Important factors in this context are debt build-up in households and enterprises and developments in asset prices.

Stress tests show how vulnerable financial institutions may be to marked – though possible – changes in economic circumstances. A stress test analyses how much may be lost, not necessarily how much will probably be lost. We have decided to use stress test scenarios in our analyses. A stress test scenario is a shift in risk factors (equity prices, exchange rates, interest rates, etc.) with a view to illustrating the effect of the shifts on, for example, financial institutions' profitability and financial strength. The ERM crises of 1992 and 1993 and the 1997 fall in equity prices are examples of changes on which a stress test scenario may be based. This kind of stress test is normally used to analyse changes resulting in negative results for financial institutions. We analyse the effect of changes on vulnerability in the financial sector as a whole rather than in individual institutions.

A number of central banks use stress testing to determine how robust the financial sector is (see for example Benito et al. (2001)). In the IMF's Financial Sector Assessment Program (FSAP), stress testing is used to analyse financial stability in member countries (see for example the FSAP for Finland (IMF 2001)). Private financial institutions also use stress testing to identify the level of risk in their activities. At the same time, the supervisory authorities are tightening their requirements with regard to financial institutions' quantitative tests of the risks associated with their activities. In the proposal for new Basel rules, banks are required to conduct stress testing when calculating new capital adequacy requirements.[2] It is proposed that financial institutions analyse the effects of macroeconomic changes on market, credit and liquidity risk. Central bank representatives from the G10 countries have charted the extent of stress testing in 43 large banks in 10 countries.[3] According to their findings, these banks performed an average of just under 10 stress tests each year.

This article presents some examples of how stress testing may be performed. We begin by explaining how stress test scenarios may be used to shed light on the risk of losses by financial institutions on loans to households and enterprises. We then discuss two macroeconomic stress test scenarios using a model-based simulation, and calculate financial institutions' losses on loans to households and enterprises in these two cases. Finally, we draw some conclusions as to what extent these events can be said to pose a threat to financial stability.

## 2 Stress test scenarios and credit risk

The banking crisis in Norway showed that there is a relationship between substantial fluctuations in the real economy and financial institutions' losses on loans to households and enterprises. This may be illustrated by means of a simple theoretical model. For a lender, the expected loan loss (TAP) will be the product of the probability of default/bankruptcy, the borrower's outstanding debt and the level of loss in the event of default/bankruptcy. We can write:

$$TAP_t = \sum_{i=1}^{n} p_{it} G_{it} TG_{it} \qquad (1)$$

where $p_{it}$ is the probability of borrower $i$ defaulting or going bankrupt, $G_{it}$ is borrower $i$'s debt and $TG_{it}$ is the level of loss given default or bankruptcy at a point in time, $t$. By aggregating the figures for all borrowers, we obtain an expression of the overall expected loan loss in the economy. The probability of bankruptcy, debt and the level of

[1] We would like to thank Eivind Bernhardsen, Thea B. Birkeland, Tore Anders Husebø, Arild J. Lund, Thorvald Grung Moe, Kjetil Olsen and Bent Vale for useful input and comments.

[2] See BIS (2001a).

[3] See BIS (2001b).

loss in the event of bankruptcy is a function of both macroeconomic developments and microeconomic conditions associated with the individual borrower. To analyse loan losses, both of these factors should be assessed.

Our analysis of the risk of losses on loans to enterprises is based on an individual-specific bankruptcy prediction model developed by Norges Bank, used in combination with the macroeconomic model RIMINI. For households, we have used aggregate figures from the national accounts and have based our analysis on the assumption that the macroeconomic model adequately describes relevant aspects related to households.

## 3 Two macroeconomic stress test scenarios

Norges Bank uses the RIMINI model to draw up projections for macroeconomic developments.[4] We have used the macroeconomic projections in *Inflation Report* 1/2002 as the baseline scenario. We can also use RIMINI to analyse alternative scenarios for the economy. In the following, we will be taking a closer look at two different scenarios for the Norwegian economy. In the first scenario, we will study the effect of a gradual fall in house prices to about 25 per cent below the level of the baseline scenario in 2004.[5] Housing wealth accounts for about three quarters of total household net wealth. A change in wealth has a relatively substantial impact on household consumption in the basic version of the consumption equation in RIMINI that we have used.[6] In this stress scenario, the fall in house prices will reduce growth in household consumption by ½ percentage point in 2002 and around 1½ percentage points in 2003 and 2004 compared with the baseline scenario. Private consumption accounts for over half of mainland GDP. The sharp fall in demand will in turn result in higher unemployment. In 2004, unemployment will be just under 1 percentage point higher than in the baseline scenario. As a result of the fall in house prices, growth in household loan debt will decline substantially compared with the baseline scenario. The interest rate is assumed to be the same as in the baseline scenario.

In the second scenario, we look at what the effects will be if wage growth is 2 percentage points higher than in the baseline scenario in 2002. In 2003 and 2004, wage growth is assumed to be the same as in the baseline scenario. At the same time, the interest rate is maintained at 2 percentage points higher than in the baseline scenario from 1 January 2002. In this scenario, we have used an alternative equation for private consumption, where real interest rates after tax have a direct effect in addition to income and wealth effects.[7] Stronger wage growth will in isolation fuel growth in real disposable income and encourage higher private consumption. However, higher interest rates reduce demand. Overall, there is a slight decline in private consumption in all the years. Unemployment is about ½ percentage point higher than in the baseline scenario at the end of the period. Higher wage growth fuels price rises, while higher interest rates help to push down price inflation. However, it takes time for higher interest rates to curb inflation. In the projection period, inflation only returns to 2½ per cent in 2004.

Stress test scenarios do not provide an indication of changes we regard as probable. They are only used to illustrate the effect on financial stability of possible shocks to the economy. The effects of the changes must be interpreted with caution. The results depend to a great extent on, among other things, the assumptions and the model used. For example, exchange rates are kept constant in both cases.

## 4 Losses on loans to households

Norwegian financial institutions' loans to enterprises and households amount to about NOK 1 500 billion. About 60 per cent of this is loans to households, primarily mortgages. In this chapter, we calculate financial institutions' losses on loans to households given the two macroeconomic stress test scenarios outlined above.

We have estimated a simple econometric model for recorded losses[8] on loans to households on the basis of developments in real economic variables (see (2))[9], where *TAPAGJ* is the financial institutions' losses on loans to households as a percentage of household loan debt, *GJELDSB* is household loan debt as a percentage of average nominal income, *RHUSBOL* is real household housing wealth,[10] *RLB* is the banks' nominal lending rate, *UAKU* is *LFS* unemployment as a share of the

$$tapagj_t = \underset{(5.7)}{3.73}\, gjeldsb_t \underset{(-7.8)}{-1.63}\, rhusbol_t + \underset{(5.5)}{13.33}\, RLB_t + \underset{(5.5)}{31.18}\, UAKU_t \underset{(24.2)}{-6.46}\, DUM97_t \quad (2)$$

4 See Olsen and Wulfsberg (2001) for a review of the methodology and how the model is used.

5 This fall in house prices does not seem very likely in the current economic situation. However, house prices have risen sharply over several years. If the rise in house prices has been stronger than fundamental conditions would indicate, so that the level of house prices is "out-of-balance", there is a possibility that house prices could fall sharply if the "bubble" bursts. However, there is little to indicate that this is the case.

6 See for example Eitrheim and Gulbrandsen (2001) for a discussion of the consumption equation in RIMINI.

7 The basic version of RIMINI probably underestimates the effect of changes in interest rates. In this version of RIMINI, consumption depends primarily on disposable income and secondarily on household wealth. Experience in recent years indicates that changes in interest rates affect private consumption faster than the wealth effect is capable of capturing. See Olsen and Wulfsberg (2001) for a more detailed explanation. It therefore seems reasonable to use the alternative consumption function in this stress test scenario.

8 Actual losses and loss provisions adjusted for reversal of previous years' loss provisions.

9 Numbers in brackets show the statistical significance (t-values) of the coefficients.

10 Measured as nominal housing wealth deflated by the consumer price index.

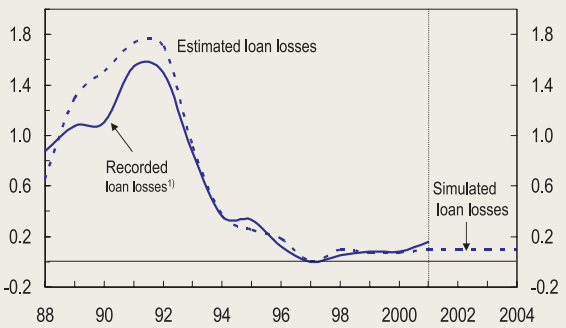
labour force and *DUM97* is a dummy for 1997. Lowercase letters indicate that we have taken the logarithm of the variables. This means that the coefficients preceding these variables may be interpreted as elasticities. Test properties for (2) are shown in Annex A.

According to the model in (2), a 1 per cent rise in the household debt burden will in isolation increase financial institutions' loan losses (as a percentage of household loan debt) by 3.7 per cent. Losses will increase by 1.6 per cent (as a percentage of household loan debt) if real household housing wealth is 1 per cent lower. This variable is an indicator of the realisation value of financial institutions' collateral. One reason why lower housing wealth has relatively less effect on loan losses than a higher debt burden is probably that many households can furnish relatively solid collateral for loans. According to the Norwegian Banking, Insurance and Securities Commission (2001), just under 70 per cent of loans from 32 banks were covered by collateral within 80% of the assessed value of a property in 2001. This share has remained relatively constant for several years. For many households, even a substantial fall in house prices would thus not result in the value of their house falling below the value of the loan. This reduces the risk of a fall in house prices resulting in financial institutions suffering losses on housing loans. A 1 percentage point higher lending rate will result in a 13 per cent increase in losses (as a percentage of household loan debt), while an increase in unemployment of 1 percentage point will result in a 31 per cent increase in losses (as a percentage of household loan debt). The equation shares many features with models previously developed by Norges Bank and the Bank of England.[11]

Chart 1 shows developments in financial institutions' actual and estimated losses on loans to households. In 2001, financial institutions' losses on loans to households amounted to NOK 1.4 billion, equivalent to 0.16 per cent measured as a percentage of household loan debt. During the banking crisis of 1991, losses amounted to over 1.5 per cent of household loan debt. The chart also shows financial institutions' loan losses up to 2004 based on developments in the real economy in the baseline scenario. According to calculations based on the baseline scenario, loan losses will remain low throughout the period.

Chart 2 shows loan losses in the two cases, measured as deviations from the baseline scenario. In the stress test scenario with stronger wage growth and higher interest rates, financial institutions' losses on loans to households as a percentage of total household debt will increase by about 0.1 percentage point, or just under NOK 1 billion in 2001 prices, compared with the baseline scenario in 2004. A somewhat lower debt burden will in isolation contribute to reducing losses, whereas higher unemployment and higher interest rates will result in an increase in overall losses in this case.

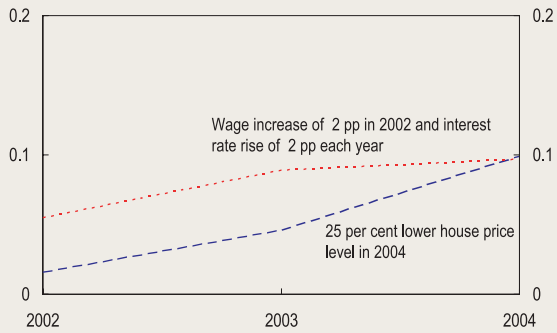
**Chart 1** Financial institutions' losses on loans to households as a percentage of household loan debt




1)Actual losses and loss provisions adjusted for reversal of previous years' loss provisions.

Source: Norges Bank

**Chart 2** Effect on financial institutions' losses on loans to households1). Deviation from baseline scenario in percentage points




1) Measured as a percentage of household loan debt

Source: Norges Bank

In the stress test scenario with a fall in house prices, losses will be slightly lower in 2002 and 2003, but on a level with the losses in the above scenario in 2004. The fall in house prices results in a substantial reduction in household consumption and housing wealth. Lower demand will contribute to rising unemployment. In 2004, losses will be about 0.1 percentage point, or just under NOK 1 billion (2001 prices), greater than in the baseline scenario.

The analysis does not reflect the fact that households are a heterogeneous group. Debt burden, for example, varies widely across the different household income deciles and has developed differently over time. See box "Household debt burden by category of household income" in *Financial Stability* 1/2002. This implies that changes in interest rates may have a very different effect on the various categories. In a more micro-based approach, financial institutions' loan losses could be modelled for the various income categories in the household sector.

[11] See Eitrheim and Gulbrandsen (2001) and Benito et al. (2001).

## 5 Losses on loans to enterprises

In order to calculate the effect of the stress test scenarios on enterprises, we have used Norges Bank's bankruptcy prediction model as well as RIMINI.[12] The bankruptcy prediction model predicts the probability of bankruptcy as a function of selected accounting variables, age, size and industry characteristics. By multiplying the bankruptcy probability for each borrower by the borrower's long-term debt and overdraft debt, we obtain an estimate of how much the lender can expect to lose in the absence of collateral. We have called this estimate risk-weighted debt. In order for us to comment on future developments in financial institutions' loan losses beyond what the model predicts on the basis of historical figures, the model's explanatory variables must be projected for each enterprise. We have done this by assuming that key revenue and expense items in enterprise accounts will vary in pace with changes in estimates for key macroeconomic variables. For example, growth in operating income is projected using estimated mainland GDP growth according to the macroeconomic projections in *Inflation Report* 1/2002 (see Annex B). It is assumed that no enterprise leaves the population and that none are added, and that the age of each enterprise remains constant.

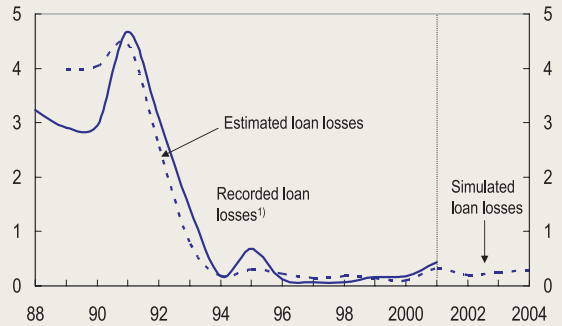
The model uses the projected accounts to generate simulated bankruptcy probabilities and risk-weighted debt. We have developed an econometric model for financial institutions' losses on loans to enterprises in which we use risk-weighted debt in combination with a variable that indicates the value of the lenders' collateral (see (3)):[13]

$$tapfor_t = \underset{(50.3)}{0.954}\ rgjeld_{t-1} - \underset{(-7.0)}{13.34}\ \Delta rph_t \qquad (3)$$

where *TAPFOR* is financial institutions' losses on loans to enterprises measured in 2001 prices, *RGJELD* is the sum of risk-weighted debt for all enterprises measured in 2001 prices and *RPH* is the real price of existing dwellings. Lower case letters indicate logarithmic form and Δ indicates the first difference of the variable. The annual change in real house prices is used as an indicator of the change in the realisation value of the lenders' collateral (see *TG* in equation (1) above). The collateral pledged by enterprises to lenders consists mainly of real estate, operating assets and inventories. However, since information about the realisation value of these assets is not available, we have chosen to use changes in house prices as an indicator. According to the model in (3), a 1 per cent increase in risk-weighted debt will increase loan losses by 0.95 per cent. A 1 percentage point reduction in the value of financial institutions' collateral will increase losses by 13 per cent. The test properties of (3) are shown in Annex C.

According to the simulations based on the baseline scenario, financial institutions' loan losses will amount to 0.28 per cent of enterprises' loan debt, or NOK 2.4 billion in 2001 prices in 2004 (see Chart 3). This is in line with losses in 2001, but a rise in relation to the latter half of the 1990s.

**Chart 3** Financial institutions' losses on loans to enterprises as a percentage of corporate loan debt

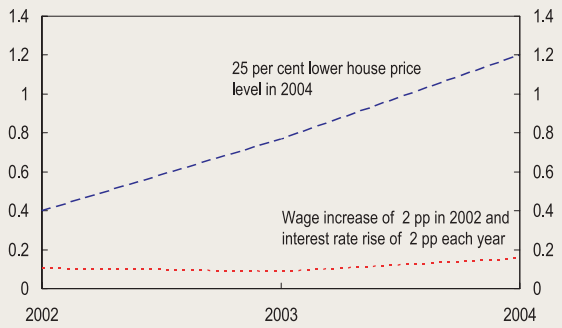



1) Actual losses and loss provisions adjusted for reversals of loss provisions for previous years

Source: Norges Bank

The scenario with higher wage growth and higher interest rates will increase financial institutions' losses on loans to enterprises by between 0.1 and 0.2 percentage point each year compared with the baseline scenario (see Chart 4). One reason for the change having little impact compared with the baseline scenario is that labour costs and interest expenses constitute a relatively small share of enterprises' total expenses in the accounts. Labour costs and interest expenses are also included indirectly to a varying degree in the cost of goods for enterprises, but this is not captured in our simulations. The effect on corporate earnings, and hence on bankruptcy probability, is thus underestimated to some

**Chart 4** Effect on financial institutions' losses on loans to enterprises.[1)] Deviation from baseline scenario in percentage points




1) Measured as a percentage of corporate loan debt

Source: Norges Bank

12) See Bernhardsen (2001) and Eklund et al. (2001).

13) Numbers in brackets show the statistical significance (t-values) of the coefficients.

extent. Another reason for the small differences is that the rise in enterprise debt is assumed to be the same in this stress test scenario and in the baseline scenario.

The scenario with a fall in house prices will result in far greater loan losses. This is to some extent due to an increase in bankruptcy probabilities, but mainly to the sharp reduction in the realisation value of financial institutions' collateral. In this case, loan losses will be 1.2 percentage points higher than the baseline scenario in 2004, but still far lower than the loss level in the early 1990s. In 1991, loan losses were equivalent to 4.7 per cent of enterprises' loan debt. One reason for the losses being far lower in this scenario than during the banking crisis is that the majority of enterprises are far more financially solid today, and are therefore better able to withstand deterioration in profitability and financial strength. Moreover, macroeconomic developments during the banking crisis were far more negative than has been assumed in the scenario with a fall in house prices.

The results of the stress tests must be interpreted with caution. There is considerable uncertainty as to how well the model captures the effects of the estimates for macroeconomic developments. It is also unrealistic to expect all enterprises to be affected to an equal extent by the various changes. Furthermore, it is natural to assume that the property industry, which accounts for a large share of enterprise sector debt, will be more severely affected than other industries by a sharp decline in the property market. In our calculations we have also assumed that some accounting items, such as other operating expenses and dividends, remain unchanged in the various scenarios during the simulation period.

One feature of the method used is that the bankruptcy probability of financially solid enterprises diminishes, while that of financially weak enterprises increases. In reality, the enterprises in the population will change over time. At any point in time, each will face individual changes with respect to earnings. Thus a favourable (poor) result one year will not necessarily be followed by favourable (poor) results in subsequent years. It may also be assumed that some of the enterprises that continue to do well will decide to make new investments, acquire other enterprises, give their owners extra large dividends, etc. Although such measures may lead to improved profitability and financial strength in the long term, they may contribute to increasing the probability of bankruptcy in the short term. Similarly, enterprises that record a poor performance may implement measures to curb the negative trend. This may help to reduce the probability of bankruptcy. Our analysis is based only on "mechanical" projections of enterprise earnings, liquidity and equity capital.

Another important factor we do not capture is the natural "dynamics" in the enterprise sector, i.e. that new enterprises are established, existing enterprises go bankrupt, are wound up, or merge, strong enterprises acquire weak ones, etc. We have not taken this into account in our analysis. There will therefore be a margin of error when the simulated risk-weighted debt is compared with the actual risk-weighted debt. The further ahead in time the accounts are projected, the larger this margin of error will be. This is partly because the (constant) simulation sample will increasingly differ from actual developments in the enterprise population.

## 6 Conclusion

In this article, we have presented some examples of how stress tests may be used to analyse the risk of financial instability. The use of macroeconomic models enables us to quantify the effects of various macroeconomic changes on financial institutions' loan losses. Our analysis has the advantage that it captures important effects resulting from the interaction between the household and enterprise sectors.

The analysis indicates that negative changes in the real economy will lead to higher losses on loans to enterprises and households. The stress test scenario with falling property prices will have by far the most negative effect on financial institutions' losses, and in particular losses on loans to enterprises. In this case, financial institutions' losses on loans to households and enterprises (measured as a percentage of household and corporate loan debt) will be about 0.6 percentage point higher than the baseline scenario in 2004. The stress test scenario with higher wages and interest rates results in a 0.13 percentage point increase in loan losses. The stress test scenarios we have examined indicate far lower loan losses than during the banking crisis in the early 1990s. However, macroeconomic developments during the banking crisis were far more negative than assumed in the two scenarios used in this analysis.

The results will to a great extent depend on the models used and the assumptions on which the scenario is based. Nonetheless, they give an indication of how vulnerable financial institutions may be in the event of changes in economic developments. Stress tests are at an early stage of development and use, and the methodology is being further developed by Norges Bank and other institutions. It is, for example, relevant to analyse to what extent any retroactive effects from financial institutions to the real economy will affect loan losses. It is likely, for example, that higher losses in financial institutions will lead to more restrictive lending practices and a closer focus on credit risk.

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## Annex A. Model of financial institutions' losses on loans to households

$$tapagj_t = \underset{(5.7)}{3.73}\ gjeldsb_t - \underset{(-7.8)}{1.63}\ rhusbol_t + \underset{(5.5)}{13.33}\ RLB_t + \underset{(5.5)}{31.18}\ UAKU_t - \underset{(24.2)}{6.46}\ DUM97_t$$

### *Properties*

Estimation period 1978-2001 (T = 24)
Sigma = 0.238342
RSS = 1.07932957
Log-likelihood = 3.16604
Durbin-Watson = 2.07

AR 1-2 test: $F(2.17) = 0.25855$ [0.7752]
ARCH 1-1 test: $F(1.17) = 0.28035$ [0.6033]
Normality: $\chi^2(2) = 1.3879$ [0.4996]
Hetero test: $F(9, 9) = 0.78893$ [0.6351]
RESET test: $F(1, 18) = 0.56228$ [0.4630]

The figures in brackets are significance probabilities.

## Annex B. Variables underlying projections of corporate accounts

The key explanatory variables in Norges Bank's bankruptcy prediction model are corporate earnings, liquidity and financial strength. Changes in these variables are mainly reflected in enterprises' operating income, the cost of goods, labour costs and interest expenses. These accounting items are influenced by a number of internal and external factors. It is unrealistic to take all the factors that influence them into consideration. We have decided to focus on the following accounting items and factors:

| *Accounting item* | *Projected on the basis of estimates for* |
|---|---|
| Operating income | Mainland GDP[1] |
| Cost of goods | Mainland GDP[1] |
| Labour costs | Annual wages and cost of additional vacation days[1] |
| Interest expenses | Norges Bank's deposit rate plus fixed additional amount for risk and administration[2] |
| Real estate and buildings[3] | Real house prices[1] |
| Long-term debt and overdraft debt | Average net increase in debt[4] |

[1] See *Inflation Report* 1/2002 and the above stress test scenarios

[2] Estimated on the basis of figures from Norges Bank's interest rate statistics

[3] Only applies to the scenario with a fall in house prices.

[4] Calculated as an average of the annual net change in enterprises' long-term debt and overdraft debt in the period 1995-2000. Source: Norges Bank

## Annex C. Model of financial institutions' losses on loans to enterprises

$$tapfor_t = \underset{(50.3)}{0.954}\ rgjeld_{t-1} - \underset{(-7.0)}{13.34}\ \Delta rph_t$$

### *Properties*

Estimation period: 1989 – 2001 (T = 13)
Sigma = 0.567296
RSS = 3.54007181
Log-likelihood = -9.99099
Durbin-Watson = 1.37
AR 1-1 test: $F(1, 10) = 0.92840$ [0.3580]

ARCH 1-1 test: $F(1.9) = 0.00059521$ [0.9811]
Normality: $\chi^22(2) = 0.41951$ [0.8108]
Hetero test: $F(4, 6) = 1.6980$ [0.2676]
Hetero-X test: $F(5, 5) = 1.1885$ [0.4272]
RESET test: $F(1, 10) = 0.013015$ [0.9114]

The figures in brackets are significance probabilities.