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Macro Stress Testing and an Application on Turkish Banking Sector[1]

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Abstract

Especially after the recent financial crisis that started in mortgage markets and spread all over international markets, in order to better monitor financial risks, the importance and use of stress testing has increased. In this study, top-down macro stress testing from a supervisory perspective was analyzed and discussed in general terms. Then, probable effects of credit, interest rate, exchange rate, and contagion risks on capital adequacy of Turkish banking sector in specified baseline and adverse scenarios were examined. First, different satellite panel econometric models for corporate and retail loans were used to estimate loan growth and non-performing loans. Second, model results were utilized to see effects of macro-economic scenarios on Turkish banking system according to the Basel's standard and economic capital approaches. Results of the study showed that economic growth and interest rates change had significant effects on corporate loans while along with these variables unemployment rate had significant effect on retail loans. Moreover, economic growth, exchange rates, and unemployment rate had significant impacts on corporate non-performing loans while only economic growth and unemployment rate had significant impact on non-performing retail loans. According to the study results, while there was no significant impact of exchange rates on net income of the sector because of low level net foreign currency positions, the main effect was on capital adequacy via revaluation of foreign currency denominated risk weighted assets. We found that the robust capital base of Turkish banking sector was a crucial factor in resilience of the sector' capital adequacy against financial shocks.

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Keywords: Stress Testing, Turkish Banking Sector, Credit risk, Interest Rate Risk, Exchange Rate Risk, GMM

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1. Introduction

We all know that in all financial interactions participants seek for the accurate financial information. This is all for the pricing of the financial instruments, valuation of the financial companies, and even for the reliability of macroeconomic indicators. In this context, banking sector is also going through this way and both for micro and macro levels, financial intermediaries and participants are continuously looking for the correct financial information to get correct decisions.

This aforementioned concern on pricing in the area of whole finance seems to be advanced in the developed countries because of their long financial history, well developed markets, and research activities. However, during economic crises we saw that markets' functioning was not always being as expected. Since financial parties realized that in the global environment they were not independent from each other and financial systems needed to be managed and supervised better, global financial supervision has been changing. International institutions, especially the Basel Committee is leading this change in global banking system.

This observed change in banking system is from the historic financial analysis based supervision to a new supervision approach focusing on financial institutions' goals, financial expectations, and probabilities. This forward looking financial expectation based supervision approach forces regulators and supervisors to act as a leading/coaching authority that helps banks to build their own internal control systems, risk management frameworks, and self-control mechanisms. Basel Banking Committee has been constantly working on new studies, principals, regulations, and approaches in this area to provide a comprehensive framework for banks that help them to conduct their activities safely by their own.

In this context, although it is not enough, capital adequacy ratio has been focused as a final, or let us say unique indicator. For a healthy bank, it is generalized to be that a certain level of capital adequacy ratio is said to be safe. Afterwards, following the recent US mortgage crisis liquidity coverage ratios were also introduced by Basel III Rules. Here comes the question. To which extend these measures are enough?

As it is known, capital adequacy ratio indicates a financial institution's capital as a resistance against losses. After the initial capital, a financial institution's loss or gain is simply the main factor for the capital. Also, losses exposed can be distinguished to expected and unexpected. Banks are expected to count their ongoing financial and operational losses and they are assumed to hold reserves for their expected losses. On the other hand, unexpected loss is the big question for banks since any unexpected loss greater than a bank's capital means default. At this stage stress testing is in charge and becomes an important tool to test if banks have enough capital in case of an unexpected but plausible event.

The purpose of this study is to present and discuss the main framework of a top down macro stress testing and in this aspect analyze Turkish banking industry's capital adequacy level within a set of scenarios. We hope that the study will give important outputs about the industry's current situation and potential. In addition we hope that it will be helpful for academics and practitioners.

2. Literature Review

Although several studies have been made about stress testing, these studies are mainly focused on a specific portfolio or a specific structure of a credit institution. Moreover, studies which are about macro-economic variables and credit risk parameters can be defined as supportive analysis for stress testing rather than being a single stress testing study. On the other hand our way of studying macro stress testing is on the supervisory perspective which focuses on a much wider scope. In this perspective we see very practical examples from International Monetary Fund (IMF).

One of an important example is Cihak's (2007) paper titled "Introduction to Applied Stress Testing". The study includes a variety of detailed methodologies and an important analysis. Besides, the importance of the study comes from the provided framework tool on an excel file. This framework is designed to provide a stress testing tool which can be adjusted to various assumptions and different data granularities to be used in IMF-FSAP (Financial Sector Assessment Program) studies in different countries.

Following that, Schimieder, Puhr and Hasan published "Next Generation Balance Sheet Stress Testing" (Schimieder *et al*., 2011) which is a much more detailed, comprehensive, and advanced study to be used by IMF and country authorities. The study introduces a more extensive dynamic methodology supported with detailed analysis to be used as rule of thumbs. These analysis and rule of thumbs are mainly about basic relations of main components, macro variables, risk factors etc. for different countries' financial structure. The study is very helpful with the provided excel stress testing tool which can be adjusted to a large number of banks with numerous assumptions in various data granularities. This sophisticated application tool which helps to provide output with intensive calculations is still used in FSAP studies and referenced in supervisory agencies.

Moreover, another working paper (Schmieder *et al*., 2012) analyzes the interaction between solvency and liquidity testing and studies liquidity testing. The study also provides a liquidity testing application with an excel based tool.

On the other hand there are various studies with different approaches but similar goals. Number of supervisory authorities and institutions reflect their own practices and approaches. One of those (Geršl *et al*., 2012) reflects Czech National Bank's stress testing approach and methodology. Moreover, Jakubik and Heřmanek's (2008) study provides similar approach and methodology. Jakubik and Schmieder (2008) studied about the application of macro stress testing on retail and commercial loan portfolios. The study which is on Czech and Dutch banking industries basically studies the nonlinear relationship among macro variables and non-performing loans.

An important example for analyzing and modeling of macro variables and stress testing is the Petr Jakubik and Fungaova's (2012) study. In this compact study a very intensive stress testing framework is used by authors to assess the resilience of Russian banking industry for a baseline and an adverse scenario for a two year period in a top down macro stress testing approach. The methodology applied is very practical, useful, and inspiring.

Notably, Kimmo Virolainen (2004) applies macro stress testing with industrial interaction and examines the contagion of shocks in risk factors to different industries. The analysis basically depends on the McKinsey's Credit Portfolio View model which is based on Wilson's (1997) study.

Another important study conducted by Altıntaş (2012) provides applied modeling examples and summary results for the Turkish banking industry giving a very comprehensive technical framework and application examples. Loan losses and macro-economic variables are econometrically modeled and forecasted intensively. It is an important study and source in stress testing for Turkish banking industry.

Beşe (2007) analyzes stress testing methodologies and applied stress testing in credit risk with VAR (Vector Auto Regression) models.

Iskender (2014) focuses both on sensitivity analysis and macro stress testing on credit risk for Turkish banking sector. The study covers intensive theory on credit risk, stress testing methodology and also the analytic application. In the analysis VAR models and time series analysis are used to forecast loan losses depending to macro scenarios. The results are linked with their final effects on capital adequacy ratios.

2.1. Stress Testing

Stress testing can be defined as an analysis to assess the effect of a significant change in a macroeconomic environment, or an extreme but plausible event on a financial institution or a system. These kind of analysis has a growing importance since it is crucial to estimate, test, and be prepared for any adverse scenario in financial markets.

Until the early 1990's stress tests have been used intensively by the international large banks and afterwards utilized by more financial institutions. Later on supervision agencies started to set standards to banks in order to monitor their own market risk with internal models. In 1996, Basel Committee (The Basel Committee on Banking Supervision- BCBS) published a document suggesting banks to use stress testing and defining some terminology about the general principles. BRSA (Banking Regulation and Supervision Agency of Turkey) also upgraded regulations accordingly in line with the international standards (BRSA, 2006a). Last but not least, in 2009, BIS (2009a) published 20 core principles on sound stress testing applications and supervision for supervision agencies and financial institutions.

Following the US mortgage crisis until mid-2007 financial institutions faced enormous losses in their trading portfolios. Most banks' market risk losses exceeded their capital requirements which were based on the application of Basel Committee's Value at Risk (VaR) methodology estimations. Since then Basel Committee realized the gap here and mandated Stressed Value at Risk methodology (BIS, 2009b). By this way banks are ensured to keep enough capital for market risk in long term stress environments.

On the other hand, Basel Committee (2012) compared supervisory authorities stress testing principals and published results. Results showed that half of the Basel member countries were still in the beginners' level and they even did not have any extensive and regular stress testing studies except the ones IMF and World Bank did in FSAPs. Though, BRSA's regularly conducted top down stress testing studies in different methods since 2002 helped to gain experience and knowhow in this area.

In the BRSA on the regulation side scenario analysis and stress testing issues were first introduced with "Banks Internal Systems Regulation" in November 2006 (BRSA, 2006b). According to the statements in Article 42 of this Regulation banks were supposed to have enough capacity to measure risk factors effect on their loss or gains; to provide a system to conduct regular stress tests and scenario analysis evaluating the effect of unexpected events on their main activities; and to provide outcomes to be evaluated regularly by top management and to be used in activities.

In June 2011, "Banks Internal Systems Regulation" was republished and Internal Capital Assessment concept was introduced as a main part of the Regulation. At the same time scenario analysis and stress testing topics were relocated in Article 69 in the Risk Reporting part of the Regulation. Also in this article, stress testing topic extended especially by imposing banks to have a more detailed stress testing program to be conducted minimum once a month which is sufficient enough regarding to banks size and the complexity of transactions. This Regulation defined stress testing as "single factor sensitivity analysis and multi factor scenario analysis which estimated the possible losses and the effect on economic capital due to possible adverse events and market conditions.

Finally in July 2014, "The Regulation on Banks Internal Systems and Internal Capital Adequacy Assessment Process" (BRSA, 2014) extensively focused on the Internal Capital Adequacy Assessment Process (ICAAP) and Stress Testing. As a part of the ICAAP, banks have to maintain their stress testing programs. This regulation imposes banks to have detailed stress testing programs consistent with their size and the complexity of transactions. Tests for market risk, counterparty credit risk and liquidity risks are to be conducted minimum once a month, however bank wide extensive stress testing with all risk factors is to be conducted at least a year. Moreover, banks' stress testing programs are supposed to be in line with the BRSA's manual (2015). Banks are also forced to apply the BRSA's scenarios if given. This regulation is very important since the interaction between stress testing results and internal capital adequacy calculations helps banks stress testing process to be as a crucial part of the ICAAP process. Doing so, the linkage between stress testing results to banks' final ICAAP results forces banks to have enough capital buffer. The BRSA has right to enforce banks to mitigate risk and/or to hold additional capital/reserve if banks have capital needs according to the stress test results.

2.2. Scenario Development and Application Methods

As stated before, although a banks maximum possible loss can be examined by Value at Risk (VaR), unexpected tail events' results could not be measured enough. Therefore, stress tests in alternative scenarios can maintain this need. Before conducting stress tests first the main risk factors should be defined. These can be interest rate risk, credit risk, exchange rate risk, liquidity risk, market risk, etc. Afterwards the type of stress test (Blacke *et al*., 2001, 11) and the scope of the test should be determined.

Later on, several scenarios should be established in order to define the size of the shocks. There are three main scenario development approaches in practice (Bolgün, Akçay, 2003, 357-358).

- Historic Scenarios: Risk variables in historic crisis periods (as in April 1994, October 2000, February 2001, 2007-2008 mortgage crisis, etc.) are applied to current variables to maintain a scenario. Latest and most significant crisis situations can also be directly taken as a scenario.

- Statistical Scenarios: Last one or two year standard deviation levels of each risk variable can be considered in scenarios.

- Hypothetical Scenarios: Defined risk variables can be considered with some deviations such as 15%, 40%, 60%, etc. Moreover worse case historic scenarios can be compounded more.

It is obvious that it would be better to use multiple type of scenarios together. However, even single factor sensitivity analyses are very important tools. Independent from each other, analyses such as increasing interest rates or FX rates in specified ranges, or decreasing credit ratings in one or two ranks can be given as examples for these sensitivity analyses.

Moreover, in terms of supervisory analysis there are two main types of stress testing applications: "top down" and "bottom up" approaches. In top down approach specified risk factors and portfolios are considered similarly in each financial institution for the same scenario. Then results can be aggregated. On the other hand in bottom up approach same scenarios are again given to each financial institution and asked to be applied by themselves in line with their own risk structures and portfolios in detail. Supervisors can later aggregate results. It is expected to get more accurate results from bottom up approach if it is applied correctly. However, top down approach can be much more practical and can provide instant outputs if adequate assumptions are used for a group of relatively homogeneous financial institutions.

3. The Methodology of the Study

In this study a top-down macro stress testing from a supervisory perspective was adopted. It is always very difficult to develop a stress testing and to apply to all banks in a system without making assumptions and generalizations. The purpose of this study is to analyze forward looking profitability and capital adequacy of Turkish banking sector under baseline and stress scenarios. The following graph is to give main process of this study's stress testing methodology.

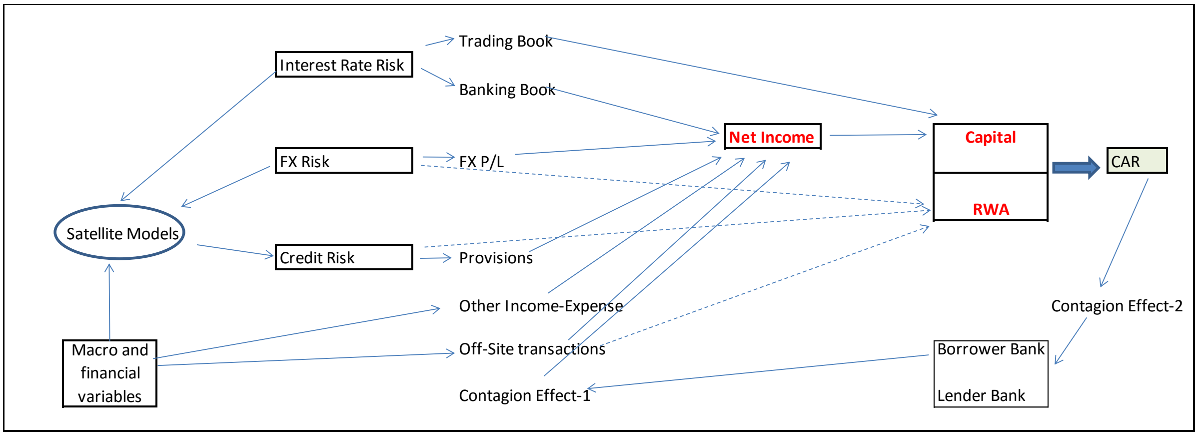

Figure 1: Summary of Macro Stress Testing Process

In order to calculate the affected capital adequacy ratio (CAR) of banks under certain scenarios, one must recalculate capital (the numerator of the ratio) and risk weighted assets (RAW, the denominator of the ratio). In the study, loan growth and credit losses were projected via satellite models. In addition, incomes (losses) due to foreign currency (FX), interest rate changes and other income (expense) items were calculated to get net income. During interest rate risk analysis, unrealized gains (losses) from trading portfolio were reflected to capital rather than net income. Receivables from banks in need of capital were considered as loss due to contagion risk. Policy actions which are conducted by policy makers after a financial shock were omitted to understand resilience of the banks without any support. Regular dividend payments were considered for only baseline scenarios.

Interest Rate Risk

In this study, effects of interest rate shocks to bank CARs were calculated through two channels. First channel is the change in market value of trading portfolio which mainly consists of fixed income government securities. While best option is to revaluate cash flows from securities according to new interest rates, an approximation like below may be used. However, one should keep in mind that the best option for very large interest rate shocks is full valuation of the cash flows.

Change in market value of the trading portfolio (ΔP) = $-D \times \Delta r \times P + 0.5 \times C \times \Delta r^2 \times P$ (1)
(D: Duration, C: convexity, r: interest rate, P: market value of the trading portfolio)

While unrealized gains (losses) from trading portfolio are not reflected in net income as an accounting rule, they are recorded as an increase or decrease under accounting and regulatory capital. Thus, unrealized gains (losses) from trading portfolio were reflected in bank capital.

The second channel that interest rate shocks will affect bank net interest income is banking book that has a mismatch according to the repricing maturities. As it is known, banks are intermediaries which collect short term funds and use that funds for longer term loans. Typically in Turkish banking sector, deposit banks collect funds in 3 month or less maturities and fund loans in 3 - 4 years maturities on average. This maturity mismatch between assets and liabilities makes banks vulnerable to interest rate increases. In order to mitigate this risk banks try to increase funding maturity via longer term syndications, securitizations, bond issues, and derivatives.

The effect of interest rate changes on net interest income can be measured as follows:

Total Interest Income: (Current Interest Income + change in Current Interest Income) + Interest Income from growth

$$TII = (CII + \Delta CII) + GII = (A_n \times r^*) + (A_n \times g \times (r_n + \Delta r_n))x0.5 \quad (2)$$

g: growth rate of assets (%);
A_n: interest sensitive assets in maturity (n);
r_n : return on assets in maturity (n) (%);
Δr_n : change in return on assets in maturity (n) (%);
r^*: weighted average of rates on assets (after change)

Weighted average of rates on assets, for instance, 15-day maturity will be calculated as follow: (15/365) x r15 + ((365-15) /365) x (r15 + Δr15). If we calculate income for 1 year later, we should change only interest rates for assets maturing in one year since other assets will be repriced later. Therefore, average of interest rates on assets maturing after 365 days will be same as beginning interest rate.

Total Interest Expense: (Current Interest Expense + Change in Current Interest Expense) + Interest Expense from Growth

$$TIE: CIE + GIE = (P_n \times r^*) + (P_n \times g \times (r_n + \Delta r_n))x0.5 \quad (3)$$

g: Growth rate of Interest Sensitive liabilities (%);
P_n: Interest Sensitive liabilities in maturity (n);
r_n : cost on liabilities in maturity (n) (%);
Δrn : change in cost on liabilities in maturity (n) (%)
r^*: weighted average cost of liabilities (after change)

An alternative way of modeling net interest income coming from growth is to use net interest margin (NIM) and projected assets:

Net Interest Income coming from growth: (ΔNII_g) = NIM x g x Average Assets (4)

However, since it is necessary to estimate or model NIM it will be useful to be conservative and take minimum near term averages. Expert judgment is unavoidable where each bank may have unique asset and liability pricing strategies to be taken into consideration. Thus, when interest rates go up, increasing margins between new loans and deposits (flows) may slow down contraction in net interest margin. In this study, to be conservative minimum of last three years' NIM was used for NII coming from asset growth.

Finally, NII will be calculated as follows:

Net Interest Income (NII): Total Interest Income (TII) – Total Interest Expense (TIE) (5)

Net interest income is the most important and largest part of net income especially in Turkish banking system.

Foreign Currency Exchange Risk

Where a change in foreign currency (FX) exchange rates may affect credit risk of clients who have FX positions, it has also direct effects on net income through net FX positions profit/loss. In that case direct FX profit/loss in local currency from a bank's FX position can be modeled as follows:

FX profit/loss = (On-balance sheet FX position + Off-balance sheet FX position) x % change in FX exchange rate

$$FX\ p/l = (ONBP + OFFBP) \times \Delta\%FX \quad (6)$$

In this study, FX risk arising from credit risk of clients who have FX positions will be taken into consideration implicitly in NPL (non- performing loan) models as FX exchange rates are used as an explanatory variable.

On the other hand, since local currency equivalence of FX denominated assets will change after FX exchange rates changes, RWA (risk weighted asset) amount that is used in CAR will change as well. RWA change due to FX exchange rate change is modeled as follows:

RWA change due to FX rates = Value of weighted credit Risk x percentage change in FX basket rates x ratio of FX denominated assets to total assets.

$$RWA\_FX = CREDIT \times \Delta\%FX\ rates \times (FX / TA) \quad (7)$$

Credit Risk

In terms of credit risk, banks' loan growth rates and non-performing loan (NPL) rates are estimated. Within credit risk calculations two alternative approaches can be used as being the "Standard Approach" and "Economic Capital Approach". While the theory and practical methodology were given for the Economic Capital Approach as well, in this study Standard Approach was applied since it was in effect in Turkey during the study.

Standard Approach

In Standard Approach credit risk was analyzed with the recalculated provisions and risk weighted assets. The loan growth and NPL were estimated through satellite models. In order to estimate loan losses near term average loan provisioning rates were applied for the expected exposures.

Next period risk weighted assets (RWA_{t+1}) estimation was considered through the following calculations.

$$\begin{aligned} RWA_{t+1} = RWA_t \; & + \Delta \text{ corporate loans*corporate loans average risk weight} \\ & + \Delta \text{ retail loans*retail loans average risk weight} \\ & + \Delta \text{ noncash loans*noncash loans average credit conversion rate *average risk weight}^{3} \\ & + \Delta \text{ commitments (risk weighted amount after consideration)} \\ & + \Delta \text{ derivatives (own risk weights)} \\ & + \Delta \text{ FX effect on RWA (EAD*}\Delta\%\text{FX*FX weight of total assets)} \quad (8) \end{aligned}$$

While retail loans were assumed to change according to retail loan growth estimations, besides corporate loans, non-cash loans, commitments and derivatives were assumed to grow according to corporate loan growth. Basically satellite model results directly go in the straightforward loss and capital recalculations as it is still used in current regulations.

Economic Capital Approach

Economic Capital Approach mainly utilizes credit risk parameters such as Exposure at Default (EAD), Probability Default (PD), and Loss Given Default (LGD). EAD and PD can be estimated through loan growth and non-performing loan (NPL) satellite models. LGD can be estimated by the house price index satellite model assuming that it is the best proxy for collaterals.

[3] Average credit conversion rates of non-cash loans considered not to be less than %45.

By the use of these credit risk parameters Expected Loss (EL) is calculated as credit risk loss. Further, by the use of capital requirement formula Unexpected Loss is calculated and risk weighted assets can be generated. With the assumption that the current credit risk, market risk and operational risk components of risk weighted assets do not change, next period risk weighted assets are recalculated with the new capital requirement of credit risk[4]. Finally, the aggregated capital requirement is multiplied by 12.5 to get the updated risk weighted assets.

Credit risk estimation starts with the Expected Loss (EL) calculations.

$$EL = PD \times LGD \times EAD \quad (9)$$

PD values can be calculated implicitly from the changes in NPL. After getting next period NPL estimation value by satellite models, current period PD value can be obtained by applying current variable values. It is assumed that next period NPL is based on the current period NPL plus the loan size with its default probability. Moreover, in order to consider the level of write-offs write-off rate (m) is included5 (Jakubik, Fungaova, 2012, 6).

$$NPL_{t+1} = NPL_t + PD^* (LOANS_t - NPL_t) - m^* NPL_t \quad (10)$$

Equation can be transformed in terms of PD[6].

$$PD = (\Delta NPL + NPL_t{}^* m) / (LOANS_t) \quad (11)$$

LGD calculations start with the current level of LGD 60%[7] is to change for the following periods regarding to HPI (House Price Index) satellite model estimations. It is because most of the loans are collateralized by real estates in Turkey and the best way to estimate this is to be with house price index changes. Besides, HPI effect is considered with a 50% elasticity coefficient for the final LGD[8]9(Jakubik, Fungaova, 2012, 6).

$$LGD_{t+1} = (LGD_t -{}^*\Delta HPI)^* 50\% \text{ elasticity} \quad (12)$$

The third variable of the expected loss, EAD, is the estimated loan amounts for the following periods with the credit growth satellite models.

On the other hand, Unexpected Loss (UL), in Economic Capital Approach can be calculated by risk weight functions10 of Basel Internal Rating Approach (IRB). By this way credit risk capital requirements are calculated with the following formulations.

-Credit Risk Calculations for Corporate Loans:

$$\text{Capital Requirement (K)} = [LGD \times N\ [(1 - R)^{\wedge -0.5} \times G\ (PD) + (R / (1 - R))^{\wedge 0.5} \times G\ (0.999)] - PD \times LGD] \times (1 - 1.5 \times b(PD))^{\wedge -1} \times (1 + (M - 2.5) \times b(PD)) \quad (13)$$

$$\text{Correlation Factor (R)} = 0.12 \times (1 - EXP\ (-50 \times PD)) / (1 - EXP\ (-50)) + 0.24 \times [1 - (1 - EXP(-50 \times PD))/(1 - EXP(-50))] \quad (14)$$

$$\text{Maturity Adjustment Factor (b(PD))} = (0.11852 - 0.05478 \times \ln (PD))^{\wedge}2 \quad (15)$$

[4] Next period credit risk capital requirement is not to be less than the previous period.
[5] m (write-off rate) is taken as 33% and assumed to be constant.
[6] Total loan is the non-performing loans deducted net loans.
[7] LGD assumptions are close to historic averages.
[8] LGD values are restricted not to be less than 45%.
[9] House price change effect is assumed to be 50% on LGD.
[10] BIS, An Explanatory note on Basel II IRB Risk Weight Functions, July 2005, http://www.bis.org/bcbs/irbriskweight.pdf

- Credit Risk Calculations for Retail Loans:

$$\text{Capital Requirement (K)} = LGD \times N[(1 - R)^{\wedge -0.5} \times G(PD) + (R / (1 - R))^{\wedge 0.5} \times G(0.999)] - PD \times LGD \quad (16)$$

$$\text{Correlation Factor (R)} = 0.03 \times (1 - EXP(-35 \times PD)) / (1 - EXP(-35)) + 0.16 \times [1 - (1 - EXP(-35 \times PD))/(1 - EXP(-35))] \quad (17)$$

This formulation is based on Basel's ASRF (Asymptotic Single Risk Factor) approach and it is recommended for Economic Capital Approach Capital Adequacy calculations. In summary, this approach basically considers systemic risk and maturity factors normally distributed and calculates the capital requirement of unexpected loss for one unit of loan. The formulation gets the total losses at first, however, later on "-PD*LGD" notation ignores the expected loss part. R stands for the correlation value which is for the systematic risk, M stands for maturity and b(PD) is for the standardized maturity adjustment factor of PD for different maturities.

At the end of the formulation we get (K) which is the required capital related to unexpected loss for a single unit of loan in terms of percentage. By multiplying with EAD, loan amount, we get the final capital requirement. Moreover, when this is multiplied with 12.5 of the 8% capital adequacy ratio we get the final risk weighted assets of related loans.

$$\text{Risk Weighted Assets (RWA)} = K \times 12.5 \times EAD \quad (18)$$

It is quite common in an Economic Capital Approach to get different capital adequacy ratios from ratios calculated with the Standard Approach. It is because in Economic Capital Approach projected risk weighted assets are much more sensitive to the forecasted PD and EAD values than the forecasted loan and NPL values in Standard Approach. That's why the PD driven risk weighted assets grow differently and capital adequacy ratios respond more sensitively in any scenario.

Credit Risk Satellite Models

The satellite models that constitute crucial part of this study essentially enables us to quantify credit risk. Most of the studies regarding stress tests are involved in measurement of portfolio credit risk or loss distribution under different risk factor scenarios.

Regarding satellite models; in Jakubik and Heřmanek's (2008) study retail and corporate portfolios were analyzed in terms of possible losses as a result of various scenarios and PDs pertaining the studied scenarios. In the paper, given the non-linear relationship among macroeconomic variables and NPL, the single factor credit risk model outlined in Gordy (2003) was constructed for Germany and Czech banking sector. This single risk factor model also sets the basis for Basel-II credit risk framework.

Virolainen (2004) is also a good sample study for application of macroeconomic credit risk stress testing modeling. In the paper, moving from inter-sectoral relationships regarding NPL, the loss distributions for different scenarios were obtained. The model was constructed by regressing logistic transformation of NPL on macroeconomic variables. Analogous to the study outlined in last paragraph, the relationship between NPL and macroeconomic variables was assumed to be non-linear and the logistic transformation was applied. Then, a system of equations was constructed containing macro variables modeled by basic AR models and the main NPL model described here.

Our study covers modeling of NPL through dynamic panel framework. The estimation of parameters was implemented using Arellano-Bond (1991) GMM (Generalized method of moments) method. The main advantage of this model is circumventing the dynamic panel bias in fixed effect panel econometric models to get more efficient estimation. The general model is as follows:

$$y_{it} = \alpha_0 + \rho y_{it-1} + \alpha_1 x_t + u_i + \epsilon_{it} \quad (19)$$

In this model, the fixed effect term u_i and lagged term y_{it-1}; would be correlated if fixed effect OLS method was applied and ρ term would be biased which displays endogeneity problem.

This bias was shown to be $-(1+\rho)/(T-1)$ as N→ ∞ in Nickell (1982).

The use of GMM estimation in dynamic panel models will enable us to eliminate potential bias described above. However, this method is more applicable in large group-size and small observation models and the reliability of J statistic referenced in GMM estimation as explained in Roodman (2006). As a result of these precautions we have implemented both fixed effect OLS and dynamic panel GMM estimations.

In the context of the methods described above, the estimation of PD and credit growth constitutes the main framework of our satellite model set. The models primarily help us estimate the trend of NPL ratio, credit growth, and house price index for a given set of macroeconomic and financial market factor scenarios.

In this study, the satellite models involving estimation of loan growth and NPL ratio were grouped into corporate and retail portfolios. Quarterly panel banks data starting in 2004 was used for grouped loans. The panel consists of 10 banks, of which the 10th is a cluster of banks smaller than first 9 banks in terms of total assets. NPL models include lagged NPL ratio and GDP as the main drivers the auxiliary variables could be log unemployment or log FX growth depending on the credit portfolio. Loan growth models included lagged log credit and GDP growth as the main drivers while auxiliary variables could be log unemployment rate and log interest rate depending on the credit portfolio.

$$lnNPLcorp_{it}=\alpha_0+\alpha_1 lnNPLcorp_{it}+\alpha_2 GDPg_t+\alpha_3\ lnUR_t+\alpha_4\ dlnFX+\epsilon_{it} \quad (20)$$
$$lnNPLRretail_{it}=\beta_0+\beta_1\ lnNPLRretail_{it-1}+\beta_2\ GDPg_t+\beta_3\ lnUR_t+\eta_{it} \quad (21)$$
$$lnCRDcorp_{it}=\theta_0+\theta_1\ lnNPLcorp_{it-1}+\theta_2\ GDPg_t+\theta_3\ dlnINTR_t+\nu_{it} \quad (22)$$
$$lnCRDretail_{it}=\gamma_0+\gamma_1\ lnNPLretail_{it-1}+\gamma_2 GDPg_t+\gamma_3\ lnUR_t+\gamma_4\ dlnINTR_t+\nu_{it} \quad (23)$$

In the models;
lnNPLRcorp:log log of NPL ratio of corporate loans
lnNPLRretail:log log of NPL ratio of retail loans
lnCRDcorp:log of corporate loans
lnCRDretail:log of retail loans
GDPg:annual GDP growth
lnFX: log FX growth
dlnINTR: log change in Benchmark bond rate

The models were estimated using dynamic panel GMM as stated above using dependent variable as the GMM instrument and lagged values of explanatory variables as exogenous instruments in the context of Arellano and Bond (1991) framework. After the estimation procedure satellite models were used to generate new NPLR and credit growth forecasts for each bank in the sector given the pre-determined macroeconomic scenarios.

The estimation results of the models are as follows:

$$lnNPLRcorp_{it}=1.267+0.929lnNPLRcorp_{it-1}-0.897GDPg_t+0.44lnUR_t+0.267dlnFX_{t-2}+\epsilon_{it} \quad (24)$$
$$lnNPLRretail_{it}=-0.453+0.969lnNPLRretail_{(it-1)}-1.267GDPg_t+0.169lnUR_t+\eta_{it} \quad (25)$$
$$lnCRDcorp_{it}=0.238+0.989lnNPLcorp_{(it-1)}+0.216GDPg_t-0.0214dlnINTR_t+u_{it} \quad (26)$$
$$lnCRDretail_{it}=0.903+0.964lnNPLretail_{it-1}+0.291GDPg_t-0.112lnUR_t-0.0406dlnINTR_t+\nu_{it} \quad (27)$$

Table 1 Estimation Output and Test Statistics

	Lag-1	GDPg	lnUR	dlnFX	dlnINTR	Intercept	Hansen-J Stat-p-val
lnCRDcorp	0.989*** (0.0113)	0.216** (0.959)	-	-	-0.0214*** (0.008)	0.238 (0.19)	0.387
lnCRDretail	0.964*** (0.005)	0.291*** (0.0255)	-0.112*** (0.017)	-	-0.0406*** (0.0059)	0.903*** (0.104)	0.41
lnNPLRcorp	0.929*** (0.0514)	-0.897** (0.33)	0.44*** (0.15)	0.267*** (0.0579)	-	1.267*** (0.520)	0.376
lnNPLRretail	0.969*** (0.0523)	-1.267*** (0.165)	0.169** (0.0825)	-	-	-0.45	0.136

*** corresponds to 0.01, ** corresponds to 0.05, * corresponds to 0.10 significance levels. Numbers in parenthesis correspond to standard errors.

Results of the models showed that economic growth, exchange rates and unemployment rate had significant impacts on corporate NPL while exchange rates had no statistically significant impact on retail NPL. This was because consumers had very low FX or FX indexed loans level. On the other hand, as an independent variable lagged NPL variable's coefficient was higher in the retail loan growth model (25) which showed that retail NPL was less sensitive to macro variables compared to corporate NPL. The autoregressive dependence in the model was high (0.93) as expected due to the stock nature of NPL ratio nominator and denominator.

As expected, loan growth was significantly affected by GDP growth and interest rates where the signs were positive and negative, respectively. In addition, unemployment was another independent variable in retail loan growth model having negative correlation with retail loan growth as expected. The signs of the coefficients were reasonable to economic sense but the autoregressive dependence was higher.

All models' coefficients, except corporate credit growth model and NPL retail model intercepts, are significant at 5% level. Model outputs and the diagnostic test results are shown at appendix.

Loss Given Default (LGD) Model

The other important parameter of economic capital approach is LGD. The modeling of LGD is more recent compared to PD and calibration of these models to real data has a growing importance. Since LGD data is generated in house by banks, a general approximation formula described in previous sections of the study was used:

$$LGD_{t+1} = (LGD - \Delta HousePrices) * elasticity \tag{28}$$

This model displays a reasonable relationship given the house prices, thus we were required to model house prices in order to extend the LGD parameter for 2 years horizon of the stress testing framework. The modeling approach to house prices was in the context of non-linear models since house prices are affected from economic factors differently conditional on the state of the economy. We selected TAR (Threshold Autoregressive) model (Enders, 2015) as a candidate non-linear model since threshold approach accounts for non-linearity and autogressive nature allowing forecasting. TAR models contain different parameters for pre-determined states or regimes of the economy. If the economy is above the threshold (δ) regime 1 is regarded as dominant while below threshold regime 2 is regarded as dominant given the two regimes in the economy. The generalization is:

$$y_t = \phi_{10} + \phi_{21} y_{t-1} + \epsilon_t, \quad if\ y_t > \delta$$

$$y_t = \phi_{20} + \phi_{21} y_{t-1} + \epsilon_t, \quad if\ y_t < \delta \tag{29}$$

The crucial part of TAR models is estimation of the threshold parameter. One common way is to apply a grid search[11], searching for threshold using all possible values of y_t.

The estimated TAR model is as follows[12]:

If the threshold is breached the model is:

$$\Delta HousePriceIndex_t = 0.099 + 0.885\Delta HousePriceIndex_{t-1} + \epsilon_t \quad (30)$$

If threshold is not breached the model is:

$$\Delta HousePriceIndex_t = -0.561 + 0.494\Delta HousePriceIndex_{t-1} + \nu_t \quad (31)$$

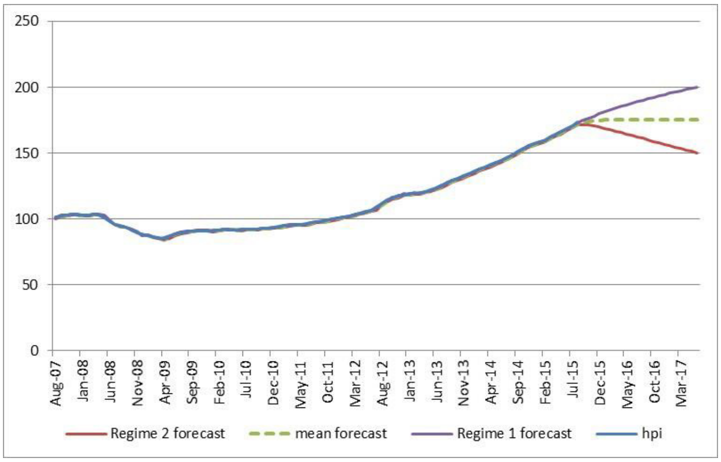

Figure 2: Model Estimations of House Price Index

As for the HPI input, we used mean forecast as baseline and Regime 2 HPI forecast for stressed economic conditions. The outputs of these models then are fed into the general formula described above to generate LGD for 2 years horizon.

Non-interest Income Expense

In this study, non-operational income items such as asset or subsidiary sales and one time realizations were excluded. As net FX position (sum of on and off- balance sheet FX position) was used during the FX risk part of the stress test, no additional FX profit/loss calculation was necessary for on-balance sheet FX position or FX derivatives.

As non-interest cost increases such as personnel and depreciation are related to banks' new investments and growth plans, it will be reasonable to increase such items in parallel to nominal GDP growth assuming reel growth and inflation are effective in cost increase. Likewise, net fee incomes/ expenses should be consistent with credit growth and past trends. Any regulation change on fee rates should be taken into consideration.

[11] The tsDYN package of R software designed for non-linear models was used for estimation
[12] The model output is given at the appendix II.

Contagion Effect

In contagion effect analysis (Jakubik, Fungaova, 2012, 8-9), net receivables (after deducting liabilities) of lender banks from defaulted borrower banks were added to loss amount of lender banks to estimate a new CAR. The main goal is to understand effect of default of a bank on other banks in the system.

One approach is to relate credit risk of a borrower bank to its PD (probability of default) dependent on CAR level[13]. If there are many counterparties and to find net position for each one is time consuming, an algorithm using “maximum entropy method” can be utilized to reach net positions by taking into consideration each bank’s share in total receivables. However, in this study real net position of each bank was used during contagion effect analysis.

Stress Testing Scenarios and Application Results

The stress testing model used in this study tried to understand how the banking system in Turkey was affected by a baseline and an adverse scenario in two year horizon. The model explained in previous sections was conducted as of June 2015 for all banks in Turkey.

The baseline scenario in question was produced by taking average of Bloomberg surveys, central bank of Turkey’s expectations survey, IMF and the World Bank country expectations for GDP growth and other scenario variables where available. Market expectations (baseline scenario) regarding basic macroeconomic variables were realized for the next two years meaning that increase in FX exchange rates, no significant change in interest rates and unemployment with a GDP growth slightly higher than 3% which is lower than potential growth.

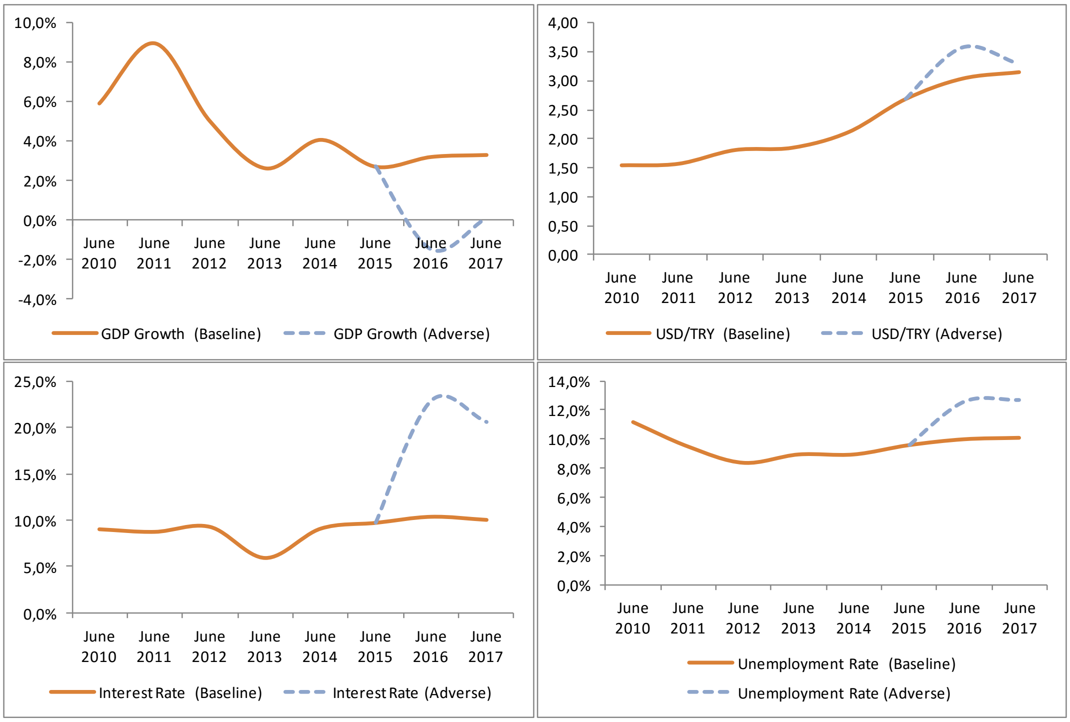

Figure 3: Baseline and Adverse (Sudden Stop) Scenarios

[13] Relation between CARs and PDs can be found by using expert judgement or rules of thumb like :100% PD for borrower banks have a CAR less than 3%, 80% PD for borrower banks have a CAR less than 5, 50% PD for borrower banks have a CAR less than 7, 15% PD for borrower banks have a CAR less than 8% etc. At the same time 10% LGD can be assumed.

On the other hand, the adverse scenario was produced according to a typical sudden stop scenario mostly adopted by IMF's Turkey FSAP (IMF, 2012) program. According to the scenario, it is assumed that after strong growth in developed countries including the USA and slowing growth in emerging markets like Turkey which lead to flight to quality and decrease in risk appetite of investors for developing countries. The scenario assumed negative GDP growth for first year and a very low GDP growth for the second year. Other assumptions included almost doubling inflation, rising benchmark interest rates over %20, unemployment exceeding 12% and USD/TRY reaching almost 3.6.

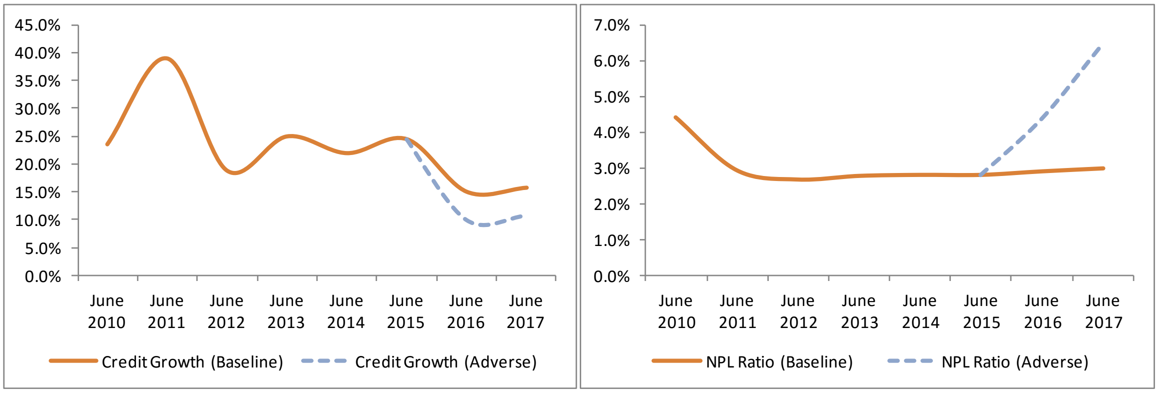

Figure 4: Satellite Model Results for Credit Growth and Non-Performing Loan Ratio

As of June 2015, assuming market expectations (baseline scenario) the CAR of Turkish banking system may decrease 1.2 points in one year and 0.6 point in the second. Two years later CAR for Turkish banks may reach to 13.6% still having 5.6 points buffer above minimum 8% regulatory level. It is very expectable to CAR to decrease due to loan and total asset growth.

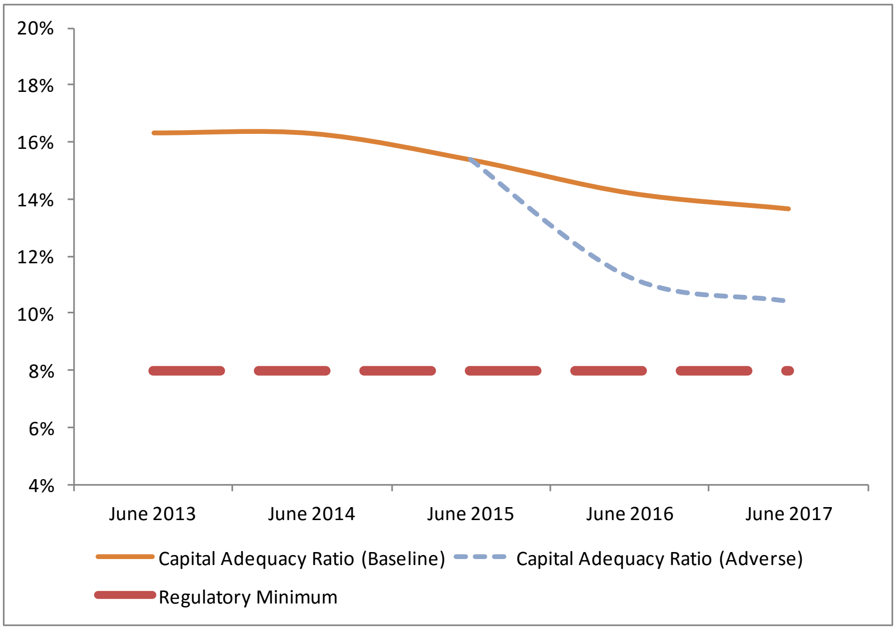

Figure 5: Stress Test Results According to Baseline and Adverse Scenarios

According to an adverse sudden-stop scenario the sector's CAR will reach to 10.4% at the end of two years, still having 2.4 points buffer above minimum 8% regulatory level.

When looked at economic capital approach which is more sensitive to inputs, estimated CARs for base and adverse scenarios go to 18% and 8% in two years, respectively.

4. Conclusion

Radical changes in financial markets have made stress tests an important and complementary tool in risk management and policy setting for both financial institutions and supervisory authorities during last decade. Stress tests have become an important channel in capital adequacy analysis both in macro and micro assessments for supervisory authorities

When looked at Turkish banking sector it is understood that despite the carried risks on bank financial reports, financial risk management systems and macro prudential measures taken by BRSA created a prudent capital buffer against financial shocks.

Results of the study showed that economic growth and interest rates change had significant effects on corporate loans while along with these variables unemployment rate had significant effect on retail loans. Moreover, economic growth, exchange rates, and unemployment rate had significant impacts on corporate non-performing loans while only economic growth and unemployment rate had significant impact on non-performing retail loans.

According to the study results, while there was no significant impact of exchange rates on net income of the sector because of low level net foreign currency positions, the main effect was on capital adequacy via revaluation of foreign currency denominated risk weighted assets. Besides, no material risk observed from interbank contagion risk. However, interest rate risk and credit risk are more important compared to others.

As a result, we found that the robust capital base of Turkish banking sector was a crucial factor in resilience of the sector' capital adequacy against financial shocks.

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APPENDIX A.

```
Estimation Results of Corporate Loan Growth:

Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: eft                             Number of obs      =       390
Time variable : donem                           Number of groups   =        10
Number of instruments = 11                      Obs per group: min =        39
Wald chi2(3)  =   8952.35                                      avg =     39.00
Prob > chi2   =     0.000                                      max =        39
------------------------------------------------------------------------------
             |              Corrected
    lnCRDcorp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lnCRDcorp |
         L1. |   .9890538   .0113149    87.41   0.000     .9668771    1.011231
             |
   dlnrgdpsa |   .2156757    .095942     2.25   0.025     .0276327    .4037186
             |
      dln3mi |
         L1. |  -.0214523   .0077098    -2.78   0.005    -.0365632   -.0063413
             |
       _cons |   .2380311   .1929629     1.23   0.217    -.1401691    .6162314
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -1.77  Pr > z =  0.077
Arellano-Bond test for AR(2) in first differences: z =   1.22  Pr > z =  0.221
------------------------------------------------------------------------------
Hansen test of overid. restrictions: chi2(7)    =   7.42  Prob > chi2 =  0.387
  (Robust, but weakened by many instruments.)



Estimation Results of NPL for Corporate Loans:

Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: eft                             Number of obs      =       380
Time variable : donem                           Number of groups   =        10
```

```
Number of instruments = 10                      Obs per group: min =        38
Wald chi2(4)  =   5669.56                                      avg =     38.00
Prob > chi2   =     0.000                                      max =        38
------------------------------------------------------------------------------
             |              Corrected
lnNPLRcorp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnNPLRcorp |
         L1. |   .9289465   .0513964    18.07   0.000     .8282115    1.029682
             |
   dlnrgdpsa |  -.8963765   .3302154    -2.71   0.007    -1.543587   -.2491663
             |
       dlnEX |
         L2. |   .2670204    .057947     4.61   0.000     .1534464    .3805943
             |
        lnUR |   .4402672   .1500831     2.93   0.003     .1461098    .7344247
       _cons |  -1.266176   .5196384    -2.44   0.015    -2.284648   -.2477035
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -2.19  Pr > z =  0.029
Arellano-Bond test for AR(2) in first differences: z =   1.30  Pr > z =  0.194
------------------------------------------------------------------------------
Hansen test of overid. restrictions: chi2(5)    =   5.33  Prob > chi2 =  0.376
  (Robust, but weakened by many instruments.)
```

Estimation Results of Retail Loan Growth:

```
Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: eft                             Number of obs      =       360
Time variable : donem                           Number of groups   =        10
Number of instruments = 11                      Obs per group: min =        36
Wald chi2(4)  =  78565.52                                      avg =     36.00
Prob > chi2   =     0.000                                      max =        36
------------------------------------------------------------------------------
             |              Corrected
lnCRDretail |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnCRDretail |
```

```
         L1. |   .9641482   .0051905   185.75   0.000      .953975    .9743215
             |
   dlnrgdpsa |   .2913397     .02552    11.42   0.000     .2413214    .3413579
      dln3mi |  -.0462478   .0058953    -7.84   0.000    -.0578024   -.0346933
        lnur |  -.1121672   .0174099    -6.44   0.000    -.1462899   -.0780445
       _cons |   .9033353   .1039352     8.69   0.000     .6996261    1.107044
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -2.50  Pr > z =  0.012
Arellano-Bond test for AR(2) in first differences: z =   0.99  Pr > z =  0.322
------------------------------------------------------------------------------
Hansen test of overid. restrictions: chi2(6)    =   6.12  Prob > chi2 =  0.410
  (Robust, but weakened by many instruments.)
```

Estimation Results of NPL for Retail loans:

```
Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: eft                             Number of obs      =       360
Time variable : donem                           Number of groups   =        10
Number of instruments = 10                      Obs per group: min =        36
Wald chi2(3)  =    370.04                                      avg =     36.00
Prob > chi2   =     0.000                                      max =        36
------------------------------------------------------------------------------
             |              Corrected
lnNPLRretail |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnNPLRretail |
         L1. |   .9692848   .0523095    18.53   0.000       .86676     1.07181
             |
   dlnrgdpsa |  -1.266831   .1652852    -7.66   0.000    -1.590784    -.942878
        lnur |   .1692285   .0825778     2.05   0.040      .007379     .331078
       _cons |  -.4533479   .2875283    -1.58   0.115    -1.016893    .1101973
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -2.41  Pr > z =  0.016
Arellano-Bond test for AR(2) in first differences: z =   1.40  Pr > z =  0.161
------------------------------------------------------------------------------
Hansen test of overid. restrictions: chi2(6)    =   9.75  Prob > chi2 =  0.136
  (Robust, but weakened by many instruments.)
```

APPENDIX B.

TAR Model output

```
Non linear autoregressive model

SETAR model ( 2 regimes)

Coefficients:

Low regime:
   const.L     phiL.1
-0.5610670  0.4944477

High regime:
  const.H    phiH.1
0.1244365 0.8703534


Threshold:
-Variable: Z(t) = + (1) X(t)
-Value: -0.3
Proportion of points in low regime: 15.73%
High regime: 84.27%


Coefficient(s):

         Estimate  Std. Error  t value  Pr(>|t|)
const.L -0.561067    0.281905  -1.9903  0.049738 *
phiL.1   0.494448    0.180710   2.7361  0.007551 **
const.H  0.124437    0.102562   1.2133  0.228346
phiH.1   0.870353    0.083203  10.4606 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Threshold
Variable: Z(t) = + (1) X(t)

Value: -0.3
```