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ABSTRACT

In this paper we investigate how well banks manage their reserves. The optimal policy takes into account expected foregone interest on excess reserves and penalty costs for going below required reserves. Using a unique panel data-set on daily clearing house settlements of a cross-section of Mexican banks we estimate the deposit uncertainty banks face, and in turn their optimal reserve behavior. The most important variables for forecasting the deposit uncertainty are the interbank fund-transfers of the day, certain calendar dates, and the interest differential between the money market rate and the discount rate – a measure reflecting the bank's opportunity cost of money holdings. For most banks the model's prediction accord relatively well with the observed reserve behavior of banks. The model produces reserves costs that are significantly smaller relative to the case when reserves are set via simple rule of thumb. Furthermore, alternative motives for holding reserves (such as liquidity and reputation effects) do not seem to be the explanation for why certain banks hold relatively large reserves.

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1 Introduction

Banks play a major role in facilitating the way the financial sector operates. The efficiency with which banks utilize reserves is important for understanding not only operational banking behavior but also for the role that banks play in the transmission mechanism. In this paper we analyze banks' reserve operations and quantify the extent to which their reserve management policy is optimal – in a sense of minimizing expected reserve costs.

The reserve management problem is interesting because of the inherent asymmetry in costs incurred by the foregone interest when the bank meets its reserve requirement and the alternative, more expensive, case in which the bank incurs a penalty cost for having reserves fall below the reserve requirement. A key ingredient in assessing the probability that the reserves of a bank will fall short of its reserve requirement is the stochastic process for the bank's deposits and withdrawals. Given this process and some other relevant state variables the bank's optimal decision can be deduced. The uncertainty and therefore the resulting reserve position at the beginning of the next day is due to the fact that certain operations of withdrawals and deposits take place after the bank sets its overnight reserve position. Therefore, much of our empirical effort is aimed at estimating this stochastic process. Given our estimates of this process we derive the predicted optimal reserve positions. Based on the latter, the actual reserve costs are compared to the estimated costs had the banks set their reserve positions according to the model. This comparison reveals the degree to which banks follow an optimal decision process for managing their overnight reserves and the costs for not doing so.

The panel data set and the environment we study are quite unique. The data set contains daily observations on the reserve positions as well as other components of the balance sheet for all banks in Mexico during the years 1990-1991. This data set allows us to estimate the stochastic process for deposits and withdrawals in a relatively precise way. During this period the Mexican banking system had a very simple structure — a feature that provides a laboratory environment for our research question. In contrast to the U.S. system, the central bank in Mexico essentially served as a payment clearing house; therefore, there were no official reserve requirements, there were no significant reputation issues such as excessive use of the discount window, nor were there any complications arising from Wednesday settlements as they were done every night. Moreover, the panel structure of the data allows us to address not only the reserve behavior over time but also systematic differences in behavior across banks. Finally, reserve management is quantitatively a significant issue. For example, during 1990 the annual reserve costs of the Mexican banking industry (equivalent to 180 million dollars) was about 10% of the industry's total profit. Thus reserve management could have an important quantitative effect on banks' overall profitability and deviation from optimal rules could translate into large reductions in the operating profits.

We find that a good forecast of the overnight withdrawals — the key variable generating overnight payment uncertainty — is based on a few types of intra-day operations. The forecasts of the overnight withdrawals result in good predictions of the reserve behavior undertaken by most banks. Overall, the model's reserve prediction seem to accord relatively well with observed reserve behavior. Specifically for 9 out of the 19 banks in our sample, we find insignificant differences between the model's predicted reserve behavior and the reserves actually used by the banks. For some banks, the model's predicted reserve position results in larger costs, although those are not statistically significant. These banks engage in many activities for which the bank is likely to have a better information set than the econometrician. For some of the other banks, the model produces somewhat lower reserve costs. For these banks, particularly the regional banks, the reserves are on average larger than what the model predicts – lending some support to the idea that other factors (such as reputation, liquidity, etc.) may govern the level of reserves. However, these alternative motives do no seem to be statistically significant. Finally, the model prediction are quite robust. The model produces reserves costs that are significantly smaller relative to the case when reserves are set via simple rule of thumb.

In terms of prior work, there are numerous classical papers on optimal cash management and the precautionary demand for money (e.g., Baumol (1952), Tobin (1958), Miller and Orr (1966), Hausman and Sanchez-Bell (1975), Frenkel and Jovanovic (1980), Whalen (1986)). Some recent papers examine more directly banks' reserve policy (e.g., Cothren and Waud (1994), Angelini (1998), Furfine (1998), Clouse and Elmendorf (1997)). Specifically, Bartolini, Bertola, and Prati (2001) examine the effect of the "reserve maintenance period" on banks' reserves and the interaction with the supply of federal funds. As in their case, our theory emphasizes the asymmetric role minimum reserve requirements and their penalty costs introduce into the reserve management problem. In particular, our empirical methodology combines panel data with non-linear time series characterization for the stochastic process for deposits and withdrawals. Our main contribution is in combining this characterization of banks' deposit uncertainty with a model for managing reserves to structurally examine how uncertainty influences banks' reserve behavior.

This paper is organized as follows. Section 2 models the optimization problem faced by a typical bank. Section 3 describes the characteristics of the data set and some specific institutional characteristics of the Mexican banking and financial sector. Section 4 describes the estimation methodology and the empirical results. Section 5 provides conclusions.

2 Model

In this section we develop a model for the optimum level of reserves for a typical bank. In Mexico, the effective reserve requirement is zero. However, a negative balance results in a penalty at a relatively high rate. This restriction lends itself to a specification in which at every period t, the bank has the objective of avoiding the penalty cost without incurring the opportunity cost due to positive excess reserves represent.[1] To introduce some notation, let

[1]Since the Mexican system does not have the two-week Wednesday clearing mechanism the problem the bank faces lacks any intertemporal aspect (at least as far as reserves are concerned) and is essentially a one period problem. It can be easily shown that the multi-period minimization problem with respect to reserve management will reduce to the one period cost minimization discussed below.

a bank start the day with a certain balance in the reserve account, y_t, where for simplicity, we eliminate the bank index i. During the day the bank performs operations in the money and capital markets that generate incoming and outgoing payments to and from the reserve account. We define od_t as the net incoming payments.

In addition to the set of operations performed during the day, od_t, there are overnight operations affecting the balance of the account. These operations come from the settlement of the nation-wide clearing houses, and they can be divided into two types. First, the bank receives check deposits during the day that are cleared only overnight, z_{1t}. Second, the bank's customers issue checks that are deposited at other banks, z_{2t}. The first type of check deposits, z_{1t}, increases the balance of the bank's reserve account. In spite of the fact that these operations are cleared during the night they are perfectly known to the bank as of 5 PM – the time the bank must set its overnight reserve position. Hence, the bank can fully anticipate the effects of z_{1t} in setting its reserve position. Deposits at other banks, z_{2t}, are withdrawals, from the bank's standpoint, and will reduce its balance account at the central bank. Note that these operations are *unknown* to the bank as of 5 PM. The uncertainty with respect to z_{2t} prevents the bank from perfectly controlling the end-of-day balance, and creates the random realization of its reserve balance at the beginning of next period.

Let Ω_{1t} denote the information known to the bank by 5 PM. This information includes the payments during the day, od_t, and the check deposits z_{1t}. Thus, Ω_{1t} depicts the state of the system when the window of operations affecting the reserve account is closed. Without loss of generality, we define the position of the reserve account at 5 PM as:

$$y_{5t} = y_t + od_t + tr_t \tag{1}$$

where tr_t is the amount the bank decides (at 5PM) to transfer to its reserve account based on the information Ω_{1t}. Note that tr_t can be negative if the bank chooses to reduce its reserve position. Following our description, the balance at the end of the day follows,

$$y_{t+1} = y_{5t} + z_{1t} - z_{2t}$$

We assume that the stochastic process z_{2t} is drawn from a cumulative differentiable distribution function $F(\cdot)$, with a corresponding probability density function $f(\cdot)$ – possibly dependent on an observable vector $X_t \subset \Omega_{1t}$. The realized reserve costs are then,

$$C_{t+1} = y_{t+1} r_t^D 1_{y_{t+1} \geq 0} + |y_{t+1}| (r_t^P - r_t^D) 1_{y_{t+1} < 0} \tag{2}$$

The first term is the foregone interest (the overnight Repo rate, r_t^D) when there are positive reserves; the second term reflects the positive costs when the reserve position is negative, in which case the investment opportunities at r_t^D has to be subtracted from the penalty costs r_t^P.[2]

The expected costs at 5 PM, when the bank has to make its transfer decision, then follows:

$$E_{\Omega_{1,t}}(C_{t+1}) = r_t^D \left[\int_0^{\infty} (y_{5t} + z_{1t} - z_{2t}) f(dz_{2t}) \right] - r_t^P \left[\int_{y_{5t}+z_{1t}}^{\infty} (y_{5t} + z_{1t} - z_{2t}) f(dz_{2t}) \right] \tag{3}$$

The first order condition for the transfer, tr, the bank ought to make at 5 PM is:

$$\frac{\partial E_{\Omega_{1,t}}(C_{t+1})}{\partial tr_t} = r_t^D - r_t^P \int_{y_{5t}+z_{1t}}^{\infty} f(dz_{2t}) = 0 \tag{4}$$

Since z_{2t} is always positive we let $\ln z_{2t}$ to be normally distributed with mean μ_t and variance σ_t. In that case, note that $\int_{y_{5t}+z_{1t}}^{\infty} f(z_{2t}) dz_{2t} = \Pr(z_{2t} \geq y_{5t} + z_{1t})$= $\Pr(\ln z_{2t} \geq \ln(y_{5t} + z_{1t})) = 1 - \Phi(\frac{\ln(y_{5t}^* + z_{1t}) - \mu_t}{\sigma_t})$, where Φ is the standard normal c.d.f. It then follows that the first order conditions can be expressed as:

[2] A bit of algebra shows that these ex-post reserve costs can more conveniently be re-written

$$C_{t+1} = y_{t+1} r_t^d 1_{y_{t+1} \geq 0} + (|y_{t+1}| [r_t^p - r_t^d]) 1_{y_{t+1} < 0} = y_{t+1} r_t^d - y_{t+1} r_t^p 1_{y_{t+1} < 0}$$

$$\Phi(\frac{\ln(y_{5t}^{*}+z_{1t})-\mu_t}{\sigma_t})=\Phi(\frac{\ln(y_t+od_t+tr_t^{*}+z_{1t})-\mu_t}{\sigma_t})=1-(\frac{r_t^D}{r_t^P}) \tag{5}$$

The transfer, tr^*, that solves (5), yields the optimal position of reserves at 5 PM, y_{5t}^*. Since $r_t^P > r_t^D$, the right hand side is a positive number between zero and one and there clearly exists a unique y_{5t}^* (tr_t^*) which solves (5). Note that Φ has time varying mean and variance, μ_t and σ_t. This is in anticipation that the distribution function will depend on an observable vector of variables X_t, and a time invariant vector of parameters θ, which we write as $\Phi(\cdot|X_t,\theta)$. Thus on any given day, the optimal position, y_{5t}^*, will therefore be a function of r_t^D, r_t^P, θ, and X_t. Thus in estimating the model, we first estimate θ using data on z_{2t} and X_t and then use the first order condition to derive the predicted optimal reserve position.

3 The Mexican Banking System

In this section we provide a brief description of the Mexican Banking system and the reserve requirements banks faced during the period of our study. The analysis performed in this paper concentrates on the years 1990 and 1991. During this period there were no major changes in the reserve requirements of the banks.[3]

The Mexican financial system is composed of the Central Bank (Banco de Mexico), commercial banks, security broker-dealer institutions, development banks and other auxiliary institutions. Commercial banks are authorized to provide investment banking services and to manage investment funds. Table 1 provides general characteristics of all Mexican commercial banks as of December 1989. These characteristics are essentially constant throughout our sample period. Within our sample period commercial banks were not required to hold reserves at the central bank. Moreover, reserves held in the central bank paid no interest. In

[3] Central Bank procedures currently curtail the use of more recent data.

spite of the fact that there were no statutory reserve requirements there was an explicit role for holding a reserve account within the central bank (with a slight abuse of terminology we will continue to refer to this account as a reserve account). These accounts, which essentially constitute the reserve system in Mexico, are used to settle inter-bank operations such as fund transfers, money market transactions, foreign exchange, cash deposits and withdrawals, and the check settlement of the clearing house.

At 5 PM, banks had to decide how much money to leave at the reserve account to support the operations generated by the settlement of the clearing house. A positive balance in the reserve account generates a holding or opportunity cost equivalent to the current market rate for overnight deposits. On the other hand, a short position generates a penalty cost at a price established by the central bank's discount rate.[4] In summary, a bank has to forecast overnight operations so that the opportunity cost of a positive end-of-day balance, and the penalty charged for overdrafts are minimized, consistent with the model outlined in the previous section.

The amount of excess reserves left in the reserve accounts and the cost of holding those reserves are significant. Consequently, improvements in the management of the reserve account can potentially generate significant cost reductions. For instance, in 1990 the reserves balances generated a combined holding and penalty cost equivalent to about 180 million dollars. These costs range from 3%-11% of the banks' financial profits. Details regarding banks profitability measures and their reserve costs are given in Table 1.

3.1 Data

The sample data comprises operations of the reserve accounts of the 19 commercial banks that operated in the Mexican financial system. The data includes operations from January 1, 1990 to November 29, 1991. Once holidays and weekends are eliminated, there are 460 data points for each of the 19 banks. The daily data was used to recreate, as much as possible,

[4] In our sample period the daily discount rate was three times the daily equivalent of the primary auction of a 28-day government T-Bill rate(Cetes).

the operational and financial picture faced by a bank when a reserve management decision was made. The leading dimension of our panel is the time series as we have data on daily operations for 19 banks.

The operational data was obtained from the archives of the high-value payment system of the Mexican Central Bank. This system tracks the operations affecting the reserve account of every bank. Using the transaction-log, we constructed time series of the operations performed by each bank. Specifically, we constructed a time series for funds transfer (ft_t), cash deposits and withdrawals (cd_t), tax related operations (tx_t), and the deposits and withdrawals generated by the check clearing process (z_{1t}, z_{2t}). Using the beginning of day balance, y_t, and the rest of the operations during the day (ft_t, cd_t, tx_t), we construct the position at 5 PM. Table 2 shows the basic statistics of these variables to illustrate their importance and volatility.

To complete the operational data, we obtained financial information relevant for the banks' decision. First, from historical financial databases, we obtained the time series that characterized the overnight penalty cost r_t^P. The overnight opportunity cost, r_t^D is the daily equivalent of the 28-day Cetes Repo Rate. Second, we obtained financial statements for each bank to compute measures of financial and managerial performance. In particular, we obtained the operating cost oc, the financial profits fp, and measures of liquidity and non-performing loans for each of these banks. Detailed information about the sources of these data sets is given in the data Appendix.

4 Estimation and Results

In this section we describe our empirical model and the estimation results. We start our analysis with standard OLS estimation of the overnight deposit settlement of the clearing house, namely estimating the process for z_{2t}. We use these OLS results as a convenient reference point and as means to justify the specific nonlinear system we consequently use.

Finally, based on the estimated process for z_{2t} we derive the predicted optimal reserve positions at 5 PM (that is y^*_{5t}) and compare them to the actual positions held by the banks.

4.1 The Settlement of the Clearing House

The key exogenous variable in terms of generating the uncertainty banks face is z_{2t}. We initially estimate a separate z_{2t} process for each of the banks in our sample. Since we do not have an explicit model for customer's check writing behavior, namely the exogenous variable z_{2t}, we simply want a good and parsimonious statistical representation for this process. We use a log specification to ensure the positivity of z_{2t}. We start with the following linear relationship,

$$\ln z_{2t} = \gamma'[1, t, CAL_t] + \sum_{l=0}^{L} \beta_l X_{t-l} + u_t \tag{6}$$

where u_t is an error term, γ is a vector multiplying a constant, a time trend t, and CAL_t a vector of calendar dummy variables, β_l is a $k \times 1$ vector of coefficients, X_t is a $1 \times k$ vector of explanatory variables, and L is the maximal number of lags used for X_t. The vector X_t contains the variables known to the bank by 5 PM and include: $\ln z_{2t-1}$, $\ln z_{1t}$, ft_t, cd_t, tx_t, vol_t, where $\ln z_{1t}$ is the log of check deposits received at the bank from other commercial banks (the counterpart to z_{2t}), ft_t is the net fund transfers, cd_t is the net cash deposits and withdrawals, tx_t is the net federal tax related operations, and vol_t is the volume of operations performed during the day.

Below we provide further description of each of the variables we use and a short explanation for how we expect each variable to effect the process $\ln z_{2t}$.

- *Check Deposits* ($\ln z_{1t}$) - A bank does not know the value of the checks deposited at other banks ($\ln z_{2t}$) but it does know the value of deposits received during the day at its own branches. The amount of deposits and withdrawals by customers is likely to be linked, and therefore deposits should provide some information on the withdrawals activity by the bank's customers. The coefficient is expected to be positive.

- *Fund Transfers* (ft_t) - Interbank fund transfers are used to settle operations such as bond purchases, foreign exchange, and many other settlements. Since many interbank operations are a consequence of an operation requested by a customer, paid by a check, a high positive correlation is expected between fund transfers and cleared checks.

- *Cash Deposits and Withdrawals* (cd_t) - A bank performs cash (currency) deposits and withdrawals at the Central Bank, to fulfill the operational vault cash requirements of its branches. Since a bank does not know the number of people that will go to the branches to perform withdrawals or cash checks, it needs to forecast this demand ahead of time. Hence, it is likely that client demand for currency is positively correlated with the demand of checking account resources.

- *Tax Collection and Disbursement* (tx_t) - The federal tax collection and disbursement is done through the branches of some banks. Also, banks distribute checks for federal payments. Thus, a positive correlation is expected between tax operations and cleared checks.

- *Calendar Dates* (CAL_t) - This vector contains a set of dummy variables capturing calendar cycles when the bank expects more checks to be cleared. The bank expects Thursdays (thu_t) to have checks with larger values than other weekdays because the settlements of primary auction of government bonds occur on that day. Similarly, days before and after holidays generate a higher volume of operation (bh_t, ah_t). Another calendar effect takes place at the middle and at the end of the month ($d1530_t$), when most workers get paid. Finally in December (dec_t) the number of check transactions is increased as companies pay Christmas bonuses and the monetary base expands.

We estimate equation (6) separately for each bank ignoring the panel nature of our data. The idea is to maintain an information structure close to that available to the banks. We start with the estimation of individual banks by running OLS of equation (6). We included all the variables mentioned above with two lags for the transaction variables $(\ln z_{1t}, ft_t, cd_t, tx_t)$[5]. The variables that were significant for all banks (with $p - value < 0.10$) were the fund transfers ft_t, tax payments tx_t, the log of check deposits $\ln z_{1t}$ and its first lag $\ln z_{1t-1}$. Other variables that were significant for most of the banks are the first lag of the clearing process $\ln z_{2t-1}$, the cash deposits cd_t, the time trend t, and the dummy calendar for Thursdays thu_t.

The number of operations vol_t was not significant. This is an indication that it is not the number of operations but the value of them that has an effect in the prediction of the mean of the process. The first and second lag of the transaction variables (ft_t, cd_t, tx_t) were consistently insignificant. Other than the Thursdays thu_t calendar variable, there was no other consistent calendar effects. An explanation of this outcome might be that the calendar peaks are already incorporated in the other transaction variables.

In summary, only 9 (including the intercept) of the 17 proposed variables were statistically significant in, at least, 70% of the banks, all with the expected signs. The larger set of variables was never chosen according to the Akaike and Schwartz BIC criteria. Guided by our desire for a parsimonious model we adopted the restricted model with 9 variables.[6]

The OLS residuals show that the variability in $\ln z_{2t}$ seem to come in clusters. Further, there is a large degree of conditional volatility with thick tails. The optimal decision (as given by equation (5) is not only a function of the mean but also a function of the variance of the clearing process $(\ln z_{2t})$. Thus, it is useful to have a framework that can predict well not only the conditional mean but also the conditional variance of the stochastic process.

To model the variance we use an Autoregressive Conditional Heteroskedastic process of order 1, denoted $ARCH(1)$ (see Engle (1982) and Bollerslev (1986)). This model suggests that large and small forecast errors appear in clusters. In this form of heteroskedasticity the

[5]We also ran the regression using the credits and debits of the transaction variables (ft_t, cd_t, tx_t) independently. For instance, using incoming and outgoing fund transfers instead of their difference. However, this separation of the variables did not improve the R^2 of the regressions.

[6]We also checked whether the Repo rate, the US Dollar/Peso exchange rate and the return on Mexican Stock Exchange had significant effect on $\ln z_{2t}$. These were marginally significant for a very small number of banks and were rejected using the BIC criteria, and therefore were not included.

variance of the forecast error depends on the size of the preceding disturbance. Thus, the framework for estimating $\ln z_{2t}$ can be written as follows,

$$\begin{aligned} \ln z_{2t} &= \gamma'[1, t, CAL_t] + \sum_{l=0}^{L} \beta_l X_{t-l} + u_t \quad \text{where} \\ h_t &= E(u_t^2 | u_{t-1}^2) = \alpha_0 + \alpha_1 u_{t-1}^2 \ . \end{aligned}$$

We use Maximum Likelihood Estimation (MLE) to determine the parameters of the conditional mean and conditional variance of $\ln z_{2t}$. The parameter estimates of the $\ln z_{2t}$ process based on the conditional variance $ARCH(1)$ specification are given in Table 3.[7] The first nine columns describe the coefficients of the conditional mean. These basically follow the patterns found using the simple OLS regression. There are reasons for why some variables are insignificant for some banks. The four banks that do not show a significant thu_t calendar effect, are not very active in the primary auction of government bonds, and therefore do not show a consistent peak of operations on Thursdays. Second, the four banks that do not show a significant coefficient for the net cash deposits and withdrawals cd_t have many cash facilities – a feature that makes the transfer of cash very flexible and so this variable is less of an indicator of future customer operations.[8]

The next three columns in Table 3, describe the parameter estimates of the conditional variance (α_0 and α_1) and the p-value of a Likelihood Ratio test comparing the homoskedastic OLS system with that of the ARCH specification. The last column provides a measure of fit via the adjusted R^2. Table 3 shows that for 12 out of 19 cases the parameter α_1 is significant. The Likelihood Ratio (LR) test confirms that the $ARCH(1)$ specification is significantly different than the one without $ARCH$ effects for almost all of the banks. Finally, to check whether the residuals from the $ARCH(1)$ estimation are indeed homoskedastic and are

[7]We also tested higher order $ARCH$ terms, however, they were not significant. We also experimented with a $GARCH(1,1)$ specification but could not reject the $ARCH(1)$ specification, except for banks 7 and 10 –see details in Table 3.

[8]Some commercial banks operate cash facilities on behalf of the Central Bank.

uncorrelated over time we regressed them on a host of variables (including lagged residuals, squared residuals, and other lagged instruments such as z_1 and z_2. The homoskedasticity was rejected for two banks; however, the inclusion of these variables directly in the estimation did not yield significant changes. The important point is that the time varying variance, σ_t, a key variable for setting next period reserves, can be modelled as locally log-normal.

We conduct a few additional experiments. We utilized some cross-bank information in estimating the clearing process. For each bank i, we included in addition to the variables described above, the variables $(\ln z_{1t}, ft_t, cd_t, tx_t)$ of banks $j \neq i$. This approach reflects the importance of cross-industry information. Presumably, the cross-industry information available to us is not available (at least in real time) to banks. This distinction is of interest because such information can potentially improve predicting the appropriate reserve position. However, in spite of the richness of these data set, the adjusted R^2 (not reported) did not show any significant improvements. This result implies that cross-bank information does not produce significant improvements in the prediction of bank i's cash withdrawal process $\ln z_{2t}$.

4.2 The Decision Process

Given the estimated process for $\ln z_{2t}$, we derive the optimal position of the reserve account established in (5). Recall that the solution for the optimal transfer tr_t^*, and therefore the optimal position at y_{5t}^*, is based on a log-normal specification for the random variable $\ln z_{2t}$. Thus, the parameters of the density function f for $\ln z_{2t}$ process characterize the conditional mean $\mu_t(\theta, X_t)$, and the conditional variance $\sigma_t^2(\theta, X_t)$.

We compute the value of the optimal position $\ln y_{5t}^*$ for every t by solving (5):

$$\ln(y_{5t}^* + z_{1t}) = \sigma_t \Phi^{-1}\left(1 - \frac{r_t^D}{r_t^P}\right) + \mu_t$$

This value of $\ln y_{5t}^*$ minimizes the combination of opportunity cost and penalty cost of the reserve account under the assumed process for z_{2t}. Formally, $\ln y^*_{5t}$ should equal the observed value for $\ln y_{5t}$ point by point. However, it is unlikely that we have the same information set as that used by the bank, and certain variables are likely to exhibit measurement errors. Consequently, we assume that the observed reserve position deviates from the predicted position by υ_t, an *i.i.d.* measurement error,

$$\ln y_{5t} = \ln y^*_{5t} + \upsilon_t \text{ where } \upsilon_t \sim N(\mu_\upsilon, \sigma_\upsilon) \ . \tag{7}$$

Equation(7) serves as an overidentifying restriction on our model. In evaluating this additional moment condition we take into account the fact that the estimates of $\ln y^*_{5t}$ depend on $f(\theta, X_t)$ which is estimated with some error.[9]

The results for the Wald test described by (7) are given in Table 4.[10] Using the critical χ^2 value of 3.85 (the 5% significance level), there are nine banks for which the model we specify is not rejected. If we reduce the critical value to 2.71 (the 10% significance level) only seven banks do not reject the model. The rejection of the model by some banks makes it evident that substantial differences can be observed across banks. To illustrate the diversity in how well our model performs in terms of predicting banks reserves, Figures 1 and 2 plot $\ln y_{5t}$ against $\ln y^*_{5t}$ for the best and worst case (bank 6 and bank 18) respectively. Theory predicts the dots should be on the 45-degree line. Bank 6 in Figure 1 has a much tighter fit in that respect.

[9] To account for the standard errors induced in estimating θ, it is convenient to think of our problem as a two stage GMM estimation procedure (see Newey (1984), Ogaki (1993)). In a nutshell, the score function of the MLE constitute the moments corresponding to the first stage estimation of θ, while the second stage is simply the overidentifying restriction implied by (7). Since the first stage is an exactly identified system, and there are no parameters to estimate in the second stage, the sum of squared errors in (7) is a Wald test distributed as a χ^2 with one degree of freedom.

[10] The υ errors, as theory suggest, are not highly autocorrelated. Using regressions υ_t were regressed on two lags of υ and one lag of z_{1t-1} and z_{2t} and were found not to be predictable.

4.3 Observed and Optimal Reserve Costs

Rejections of our model for reserves can be the outcome of either banks outperforming our model or alternatively banks not following an optimal cost minimization policy. To get a better insight of the decision process, we compare the cost incurred by each bank to the one implied by the optimal value y^*_{5t}. That is, we add the ex-post observed z_{1t} and z_{2t} to the decision value y^*_{5t} to obtain the optimal end-of-day balance y^*_{t+1}. We then compute the daily cost implied by the optimal decision by using y^*_{t+1} in the cost function (2) and summing these values for the whole sample $C^* = \sum_{t=1}^{T} C_{t+1}(y^*_{t+1})$. Analogously, we compute the overall costs based on the ex-post observed daily costs as $C^{ob} = \sum_{t=1}^{T} C_{t+1}(y_{t+1})$.

The first two columns of Table 5 provide a comparison of the cost based on the actual value y_{t+1} and those based on y^*_{t+1}. The third column shows the difference between the two. The costs based on y^*_{5t} outperform those based on the observed reserve positions for 7 of the 19 cases.[11] These results highlight a few issues. First, in terms of point estimates, 12 banks achieve better reserve position than is implied by the model (that is the costs based on y^*_{5t} are higher than those based y_{5t}). It it is quite plausible that these banks have more information than we do. A source of this additional information could be details of wholesale operations that bank treasurers usually know and that we cannot observe. In other words, in some cases banks are aware of wholesale operations that will be settled by checks. These operations are subcomponents of z_{2t} of which we only have an aggregate measure. Second, our model performs better in 7 banks. This outcome is an indication that some banks do not use information efficiently or as we discuss below have some alternative objective in terms of reserves than the one given by (4). Nonetheless, it is interesting, that in spite of the fact that the information used in our analysis is at best equal to what the banks had at the time they

[11] In an attempt to improve the model's fit of (6) and therefore the prediction efficiency we tried several other approaches. In particular, we tried to use the full information set increasing the number of variables in the model to 17. The result of this exercise was an average improvement in the cost of about 0.05%. However, this improvement did not help the model to outperform the banks reserve policy in any of the cases in which the banks outperformed the model.

made their decision, our model still managed to outperform the observed costs.[12] Moreover, in all of the 7 cases that our model outperforms actual costs, the Wald test based on the reserve decision rejects the model – indicating that analyzing the relative costs is informative beyond the statistical evaluation of equation (7).

It should be kept in mind that the cost estimated by our model, C^*, is a function of the variable y^*_{5t} which in turn is estimated with some error. Based on the standard error of the random variable C^*, we create a one-sided test that considers whether the observed cost C^{ob} is greater or equal to the estimated cost C^*. When we construct this test we observe that none of the banks reject the hypothesis. That is, once standard errors are incorporated no banks' observed costs can be claimed to be larger than the estimated optimal costs. This in some sense provides the strongest evidence for the claim that banks operate their reserves policy quite well — either better than the model or statistically not more costly.

To further analyze the model's quantitative implications for reserve costs we also compare the model's costs to the case when the bank follows some simple rule of thumb when setting its reserves. We use two alternative rule of thumbs. In the first case reserves are set so that $E_t[y_{t+1}] = 0$. In the second case reserves are based on the unconditional mean and variance of z_{2t}. The first rule is motivated by a 'naive' bank that wants to set expected reserves to zero. The second rule ignores any time variation in the mean and variance of the clearing process. These costs are depicted in Table 5 under the columns of $C^*(E_t(y_{t+1}))$ and $C^*(Ez_{2t})$ respectively. These columns clearly demonstrate a large deterioration in reserve costs relative to that implied by our baseline model. This shows that the optimal decision rules imply distinct outcome relative to these simple rule of thumb and thus lending further support for the model. Finally, the column marked *panel* in Table 5 shows the costs predicted by the model when the panel's (as oppose to individual) law of motion for $\ln z_{2t}$ is imposed. Again, the restrictions imposed by the panel estimation imply significant deterioration in

[12] One caveat is that in spite of using rolling basis for computing the reserve costs, the parameters estimates for $\ln z_{2t}$, the clearing process, are based on the whole sample. This is just a finite sample issue. Our results are not sensitive to using sub-sample estimates for the clearing process.

average costs – 2.37 times larger than the estimated costs using bank-specific process.

4.4 Alternative Motives for Reserves

Our approach thus far considered a relative simple environment where banks care only about the financial costs associated with reserves. The Mexican system is simpler than that of the U.S. and there is no explicit discount window procedure. Nonetheless, one may conjecture that reputational concerns may induce banks to hold a larger quantity of reserves than the model would otherwise predict. For example, banks may hold more reserves than the model imply due to other 'liquidity' needs or to discern any problematic features in their balance sheet such as a large fraction of non-performing loans. One indication of this is that in general the model produces more negative events than what is actually observed. The discrepancy can be quite large. For example, bank 18 (bank 5) produces 100 (83) negative cases in the data while the model produces 144 (206) cases. In addition, the last two columns of Table 4 indicate that there is some evidence that the model tends, on average, to set bank reserves below what they in fact were. In light of this, we regress the realized excess reserves $y_{t+1} - y^*_{t+1}$ on a measures of liquidity and the fraction of non performing loans (both are defined in the data appendix).

First, we regress, in the cross-section, the excess reserves on the fraction of their non-performing loans at the beginning of our sample. The idea is that those banks with a larger fraction of non-performing loans would tend to hold more reserves – thus a positive coefficient is expected. A similar argument holds with respect to liquidity. Banks with less liquidity require more reserves and thus a negative coefficient is expected. The regression results are reported in Table 6 Panel-A where we use for each bank its average quantities over the sample. First, note that these results should be taken with caution as there are only 19 banks in the cross-section. The liquidity measure has the right sign but . The non-performing loan measure is significant and positive. Next, we use the time series and relate each banks' daily excess reserves to its non-performing loan in the previous month.[13] We now run a pooled regression for the banks. Liquidity still shows up negatively, while non-performing loans shows up positive but insignificant. Finally, we ran each bank's excess reserves on its liquidity and non-performing loans separately. The results (not displayed) indicate that only five banks out of 19 have a significant positive coefficient. Moreover, of these five banks only one, bank 16, is a bank for which the model results with lower costs than the observed ones. In all, the evidence supporting these specific alternative motives for holding reserves is quite weak.

4.5 Other Factors and Reserve Costs

We investigate whether the efficiency of managing reserves measured as C_i^{ob}, is correlated with financial profits. Financial profits, fp_i, are interest charged to customers net of interest paid by the bank. The idea is that banks that are good at managing their investment portfolio would also be good at managing reserves — hence generating a negative relationship between fp_i and C_i^{ob}. Operating costs, oc_i, reflect expenses incurred by a bank in performing its regular operations, such as employee salaries. Low operating costs may be an indication of administrative efficiency. Thus a positive correlation between oc_i and C_i^{ob} is an indication that administrative efficiency is perhaps also associated with good reserve management.

We ran a cross sectional regression of the observed costs, C_i^{ob} on a constant, the financial profits fp_i, the operating cost oc_i, a dummy for the regional banks, the number of checking accounts (thousands) at each bank $check_i$, and the number of branches $bran_i$ – the latter two variables capturing some measure of size. Panel C in Table 6 shows that the variables oc_i and $check_i$ are positive and significant at the 5% significance level, whereas fp_i is negative and significant at the 10% level. The negative sign on fp_i is an indication that good financial performance is associated with a low cost C_i^{ob}. Similarly, the positive sign of oc_i indicates that on average banks that are have low operating costs also tend to have low reserve

[13]This financial information is only available to us at a monthly frequency and we assume it is constant throughout the month.

costs.[14] Given the size of the cross-section, these results need to be interpreted with caution. However, they suggest that reserve management performance is likely be correlated with other performance measures of banks.[15]

5 Conclusions

We formalize banks' reserve decision and characterize empirically, in the context of the Mexican financial system, some of the factors that influence the reserve management behavior. This system is unique in its simplistic institutional structure and affords an environment that is very close to the one studied in models of optimization under uncertainty of cash management. The data set provides a unique opportunity for investigating the banks' reserve management behavior as it includes the daily positions in the central bank of all private banks in the system.

We identify the intra-day variables that govern the law of motion of overnight deposits — the uncertain component banks face in setting their reserves. Empirically it is important to allow this process to have time-varying volatility and certain time dummies. We examine empirically how banks set their reserves in light of this uncertainty. Statistically, none of the banks seem to have significantly larger costs than what is predicted by the model. This is a striking example in which economic agents do not seem to behave systematically different than what theory would predict. We show that model leads to reserve costs that are significantly lower than the costs that would be associated with the use of alternative simple rule of thumb – lending further support to the model. Finally, although banks tend to hold on average more reserves than the model predicts, there is little support that this is due to some liquidity and reputation concerns.

[14] The same regression using operating profits yields similar estimates – indicating the results with financial profits are not merely a mechanical result.

[15] An additional interesting feature arising from informal inspection of Tables 4 and 5 suggests that geographical location may also influence reserve costs. In particular the banks which appear significantly more efficient than the model are regional banks. That is, they do not have branches nation wide and their headquarters are outside Mexico City. Hence, the limited geographical dispersion may be helpful in managing the reserve account.

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A Data Sources

- *Boletin Estadistico, Comision Nacional Bancaria y de Valores.* This bulletin contains the monthly accounting and statistical figures of the banks operating in the Mexican Financial System. We use this source to obtain the financial data given in Table 1 and the variables for the cross sectional evaluation. This source also provides measures for financial profits fp, operating cost oc, as well as measures of non-performing loans (npl) and liquidity. Non-performing loans are defined as those loans that have not received a payment in the last 6 months. Liquidity is defined as vault cash, cash at other banks and the central bank.

- *Informacion Economica, Banco de Mexico.* Database maintained on the World Wide Web (www.banxico.org.mx) and updated by the Central Bank of Mexico. This data source was used to obtain the US Dollar/Peso foreign exchange figures and the rates of the primary auction of Government Bonds that is the base for the penalty rate r_t^P.

- *Modulo Banca.* An information system at the Central Bank with a database that keeps historical information of operations performed by financial institutions. This information includes all the operations affecting the reserve account such as the clearing house settlements (z_{1t}, z_{2t}), the fund transfers (ft_t), the cash deposits (cd_t) and the tax related operations (tx_t). In like manner, this database contains the starting monthly balances of the reserve account (y_t) that is also used to compute the balance at the time of the decision ($y5_t$).

- *Boletin Bursatil, Dinero y Valores, Bolsa Mexicana de Valores.* Published by the Mexican Stock Exchange (MSE), this bulletin contains general information of the activity on the money and capital markets. The indicators include: the price index of the MSE, the volume of operations in the capital market, the volume of operations in the money market and the liquidity indicators (REPO rates) used as the opportunity cost r_t^D.

Table 1
Basic Statistics of the Mexican Banks

Bank	Assets	Liabilities	Employees	Branches	Checking Accounts	Reserves	Liquidity	NPL	Financial Profits	Total Profits	$\frac{\text{Cost}}{\text{Financial Profits}}$	$\frac{\text{Cost}}{\text{Total Profits}}$
1	154	134	770	37	14.6	5.1	2.4	7.9	22.9	9.2	0.03	0.02
2	928	867	5081	127	68.0	28.4	3.1	49.7	95.4	21.0	0.04	0.18
3	600	569	2970	100	56.3	-93.7	9.9	19.9	46.9	-8.0	0.06	0.35
4	669	604	4143	156	84.6	9.4	8.6	39.4	108.1	68.2	0.04	0.06
5	850	752	3213	117	69.0	9.9	4.8	27.8	144.9	99.4	0.02	0.03
6	873	850	2333	67	27.3	4.5	6.9	126.2	37.6	5.6	0.10	0.69
7	15669	14507	35492	761	876.6	1097.7	87.1	710.7	1096.1	705.0	0.03	0.05
8	801	745	3667	121	65.5	22.9	8.2	45.9	41.6	-9.3	0.07	0.31
9	8450	8068	20436	632	479.8	104.9	68.2	373.3	496.7	165.1	0.08	0.23
10	842	790	4289	130	51.5	11.1	27.1	54.6	88.9	39.2	0.03	0.08
11	1384	1318	6965	205	112.2	17.3	9.9	115.2	91.2	-19.1	0.05	0.26
12	1812	1678	7255	295	137.4	78.9	53.8	148.1	133.1	7.2	0.06	1.07
13	342	249	2877	71	29.5	6.92	5.1	15.8	80.3	66.0	0.02	0.02
14	3004	2852	12336	382	156.7	48.6	28.8	174.5	273.3	48.4	0.03	0.17
15	753	706	3397	87	46.5	27.8	4.5	140.9	80.0	17.0	0.04	0.21
16	18104	16980	29482	749	318.3	254.7	84.7	1052.7	1104.7	583.3	0.03	0.06
17	3429	3235	12209	345	279.2	- 798.2	30.5	166.3	293.5	107.0	0.12	0.32
18	747	719	985	22	8.8	-3.33	1.71	15.4	23.2	7.4	0.11	0.33
19	731	656	2767	103	27.6	10.4	8.91	35.3	77.2	44.3	0.03	0.06
Total	60143	56279	160667	4507	2909	799.4	454.3	3330.8	4336	1957	0.05	0.11

Financial figures for stock variables represent the status of the banks at the beginning of the sample period. Financial figures for flow variables are for the period from January 1990 until December 1990. All figures are in 1990 US dollars. Checking accounts are in thousands. Total Profits = financial profits + operating profits - operating costs. Costs refer to the costs of managing the reserve accounts. Data source: Boletin Estadistico, Comision Nacional Bancaria, December 1990. As with other stock variables, reserves, non-performing loans NPL, and liquidity are as of January 1990, and are defined in data appendix.

Table 2
Summary Statistics for Operations and Reserves

	Operations	Value	Std. Dev.
Fund Transfers	1,861	2,970	1,481
Cash Deposits	951	191	154
Tax Operations	240	421	210
Checks	2,858	9,863	3,640
Reserve Balance		713	154

The figures in this table pertain to 460 daily observations of the operations of 19 banks for the period January 1990 to November 1991. The figures for Fund Transfers, Cash deposits, Tax Related Operations and Checks include the sum of credits and debits. *Operations* refers to the average number of operations in a day. *Value* refers to the average value of total operations in a day in equivalent of millions of dollars. *Std. Dev.* refers to the standard deviation of the average amount of operations in a day.

Table 3 :Estimated coefficients of the ARCH(1) regression on lnz_{2t}

Bank	c	$\ln z_{2t-1}$	t	$\ln z_{1t}$	$\ln z_{1t-1}$	cd_t	ft_t	tx_t	thu_t	α_0	α_1	LRT	Adj-R^2
1	1.21	-0.12	0.07	0.55	0.15	-33.40	-20.68	-24.77	0.15	0.21	0.12	0.06	0.60
	(0.15)	(0.04)	(0.02)	(0.03)	(0.03)	(10.40)	(1.13)	(2.55)	(0.07)	(0.02)	(0.07)		
2	1.65	-0.17	0.06	0.68	0.15	-5.54	-3.24	-4.11	0.06	0.06	0.17	< 0.01	0.73
	(0.12)	(0.02)	(0.01)	(0.02)	(0.02)	(1.92)	(0.13)	(0.34)	(0.04)	(0.00)	(0.06)		
3	0.36	-0.19	0.05	0.82	0.25	-8.03	-5.04	-5.81	0.09	0.15	0.29	< 0.01	0.63
	(0.20)	(0.05)	(0.02)	(0.04)	(0.05)	(1.67)	(0.31)	(0.52)	(0.06)	(0.01)	(0.07)		
4	2.14	-0.30	0.15	0.55	0.19	0.88	-6.12	-6.04	0.31	0.24	0.09	0.01	0.66
	(0.17)	(0.03)	(0.03)	(0.03)	(0.03)	(5.53)	(0.76)	(0.79)	(0.08)	(0.02)	(0.05)		
5	1.90	-0.13	0.07	0.46	0.17	-18.13	-6.6	-8.08	0.24	0.18	0.05	0.31	0.50
	(0.22)	(0.03)	(0.02)	(0.04)	(0.03)	(2.34)	(0.53)	(1.33)	(0.08)	(0.02)	(0.04)		
6	0.60	-0.15	0.01	0.89	0.16	-3.71	-1.83	-1.67	0.01	0.002	0.13	< 0.01	0.77
	(0.14)	(0.02)	(0.01)	(0.02)	(0.02)	(2.77)	(0.03)	(0.03)	(0.02)	(0.000)	(0.02)		
7	1.36	-0.06	0.02	0.72	0.12	-0.03	-0.21	-0.23	0.03	0.004	0.157	< 0.01	0.89
	(0.05)	(0.02)	(0.00)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.01)	(0.00)	(0.06)		
8	1.71	-0.09	0.05	0.59	0.10	-8.19	-6.33	-6.20	0.24	0.09	0.00	0.90	0.72
	(0.19)	(0.03)	(0.01)	(0.03)	(0.03)	(1.37)	(0.27)	(0.53)	(0.06)	(0.01)	(0.04)		
9	1.19	0.00	0.03	0.74	0.11	0.21	-0.42	-0.52	0.03	0.06	0.34	< 0.01	0.77
	(0.22)	(0.03)	(0.01)	(0.03)	(0.03)	(0.33)	(0.04)	(0.02)	(0.04)	(0.00)	(0.07)		
10	0.79	-0.19	0.07	0.83	0.19	-2.74	-2.42	-2.54	0.01	0.002	0.12	< 0.01	0.87
	(0.12)	(0.03)	(0.02)	(0.03)	(0.03)	(1.10)	(0.13)	(0.11)	(0.03)	(0.000)	(0.01)		
11	2.26	-0.06	0.01	0.46	0.15	-9.02	-3.35	-4.05	0.16	0.13	0.03	0.36	0.46
	(0.24)	(0.04)	(0.01)	(0.03)	(0.03)	(1.91)	(0.24)	(0.31)	(0.06)	(0.01)	(0.04)		
12	1.27	-0.11	0.04	0.72	0.17	-2.69	-1.96	-2.71	-0.03	0.05	0.27	< 0.01	0.83
	(0.12)	(0.04)	(0.01)	(0.02)	(0.03)	(0.98)	(0.13)	(0.23)	(0.04)	(0.00)	(0.06)		
13	1.46	-0.12	0.02	0.57	0.15	-15.64	-11.23	-10.93	0.36	0.06	0.12	0.05	0.78
	(0.08)	(0.02)	(0.01)	(0.02)	(0.02)	(1.82)	(1.11)	(0.78)	(0.06)	(0.00)	(0.07)		
14	1.14	0.03	0.04	0.69	0.07	-2.75	-1.80	-1.95	0.12	0.07	0.21	< 0.01	0.76
	(0.18)	(0.03)	(0.01)	(0.03)	(0.03)	(0.85)	(0.09)	(0.11)	(0.05)	(0.01)	(0.07)		
15	1.48	-0.06	0.09	0.54	0.17	-7.63	-2.74	-4.03	0.10	0.26	-0.02	0.87	0.42
	(0.29)	(0.04)	(0.02)	(0.05)	(0.03)	(3.17)	(0.18)	(0.50)	(0.07)	(0.01)	(0.03)		
16	1.00	-0.12	0.01	0.80	0.17	-0.99	-0.88	-0.92	0.07	0.04	0.21	< 0.01	0.70
	(0.25)	(0.04)	(0.01)	(0.02)	(0.03)	(0.26)	(0.04)	(0.14)	(0.03)	(0.00)	(0.06)		
17	0.86	-0.04	0.01	0.81	0.13	-0.42	-0.16	-0.17	0.05	0.01	0.54	< 0.01	0.91
	(0.08)	(0.03)	(0.00)	(0.01)	(0.03)	(0.10)	(0.01)	(0.01)	(0.02)	(0.00)	(0.11)		
18	0.86	-0.15	-0.06	0.77	0.20	11.33	-4.50	-8.40	0.03	0.27	-0.01	0.62	0.58
	(0.22)	(0.04)	(0.02)	(0.04)	(0.04)	(14.69)	(0.15)	(2.76)	(0.10)	(0.01)	(0.02)		
19	0.52	-0.12	0.03	0.80	0.20	-11.39	-5.55	-6.30	0.033	0.04	0.16	< 0.01	0.87
	(0.10)	(0.02)	(0.01)	(0.01)	(0.02)	(3.64)	(0.23)	(0.22)	(0.03)	(0.00)	(0.04)		

Entries are ARCH(1)-MLE estimates of $\ln z_{2t}$, where $\ln z_{2t} = \gamma'[1, t, CAL_t] + \sum_{l=0}^{L} \beta_l X_{t-l} + u_t$ and $h_t = E(u_t^2|u_{t-1}^2) = \alpha_0 + \alpha_1 u_{t-1}^2$. LRT is the p-value of the Likelihood Ratio Test comparing homoskedastic and ARCH(1) $\ln z_{2t}$. t is time trend, $\ln z_{1t}$ are check deposits, cd_t are net cash deposits and withdrawals, ft_t is net fund transfers, tx_t is net operation related cash, and thu_t is dummy for Thursdays. For Banks 7 and 10 we use a GARCH(1,1). The additional coefficient on lagged volatility is 0.81 (0.02) for bank 7 and 0.84 (0.04) for bank 10.

Table 4
Testing the Reserve Decision Model (Wald Test)

bank	χ^2	$p - value$	$\bar{y}_{t+1}$	$\bar{y}^*_{t+1}$
1	2.16	0.14	2.76	1.40
2	2.93	0.09	12.28	4.86
3	0.79	0.37	8.96	6.27
4	15.72	<0.01	14.41	3.45
5	5.09	0.02	8.26	2.05
6	0.07	0.79	13.52	13.29
7	3.69	0.06	125.81	65.41
8	7.94	<0.01	12.37	3.45
9	5.03	0.02	148.66	38.20
10	0.24	0.62	10.38	10.37
11	8.39	<0.01	22.19	4.15
12	8.32	<0.01	31.23	8.60
13	20.72	<0.01	7.91	1.3
14	2.70	0.10	29.26	11.02
15	1.28	0.26	13.00	6.06
16	6.53	0.01	88.72	18.98
17	0.29	0.59	133.51	67.20
18	22.99	<0.01	9.40	2.75
19	4.74	0.03	8.70	3.45

The χ^2 column shows the values of the Wald test applied to the over-identifying restriction $E[\ln y_{5t} - \ln y^*_{5t}] = 0$.

Table 5
Actual vs. Estimated Cost

Bank	C^*	C^{ob}	Δ	$C^*(Ey_{t+1})$	$C^*(Ez_{2t})$	$C^*(Panel)$	$\frac{C^*}{check}$	$\frac{\Delta}{check}$
1	1.94	1.12	0.82	7.40	3.78	2.98	0.13	0.06
2	6.37	5.49	0.88	32.81	14.37	9.45	0.09	0.01
3	6.43	4.51	1.92	27.27	12.83	9.22	0.11	0.03
4	6.94	6.05	0.89	23.20	13.65	8.49	0.08	0.01
5	4.10	3.73	0.37	15.85	6.60	6.36	0.06	0.01
6	10.20	5.82	4.38	67.48	32.33	17.62	0.37	0.02
7	60.48	50.62	10.71	486.63	239.46	150.44	0.07	0.01
8	4.16	4.68	-0.52	19.81	9.15	8.12	0.06	-0.01
9	50.31	58.61	-8.30	269.99	136.17	62.73	0.10	-0.02
10	7.88	5.17	2.87	46.77	35.65	12.09	0.16	0.06
11	7.48	8.52	-1.06	32.89	11.96	11.56	0.07	-0.01
12	10.90	12.00	-1.10	58.30	34.57	14.96	0.08	-0.01
13	1.76	2.77	-1.01	8.48	4.59	3.16	0.06	-0.03
14	15.25	12.71	2.54	68.56	36.62	20.95	0.01	0.02
15	8.92	5.78	3.14	38.48	14.51	14.40	0.19	0.07
16	24.00	45.19	-21.19	140.12	51.16	30.86	0.08	-0.07
17	67.51	61.44	6.07	579.62	296.40	322.87	0.24	0.02
18	3.53	3.66	-0.13	18.85	8.44	5.85	0.40	-0.01
19	3.95	3.64	0.31	23.44	12.91	0.14	0.01	

$C^* = \sum_{t=1}^{T} C_{t+1}(y^*_{t+1})$ illustrates the opportunity and penalty cost, in millions of dollars, incurred by a bank during our sample period. y^*_{t+1} is the optimal end-of-day value given by the model. $C^{ob} = \sum_{t=1}^{T} C_{t+1}(y_{t+1})$ is the observed cost and y_{t+1} is the observed decision value. Δ depicts the difference between the cost generated by the use of the model of individual banks and the actual cost $\Delta = C^* - C^{ob}$. $C^*(Ey_{t+1})$, describe the costs based setting the reserves according to the previous day. $C^*(z_{2t})$ provides the costs based on setting reserves to the previous days's z_{2t}. $C^*(Panel)$ illustrate the costs based on decision rules using the optimal decision y^*_{t+1} generated by the panel model. *check* depicts the number of checking accounts (in thousands) managed by each bank.

Table 6
Cross-Sectional Evaluation of $y_{t+1} - y^*_{t+1}$, and C^{ob}

			Regressors				
const.	NPL	Liquidity	checks	fp	oc	region	R^2
			Panel A: Dependent variable – $\bar{y}_{i,t+1} - \bar{y}^*_{i,t+1}$				
10.11	4.73		21.99				0.73
(9.56)	(2.29)		(10.28)				
17.89		4.94	38.57				0.65
(25.71)		(3.89)	(14.21)				
			Panel B: Dependent variable – $y_{i,t+1} - y^*_{i,t+1}$: Pooled				
2.69	3.18		18.92				0.32
(9.56)	(1.89)		(10.26)				
12.47		2.04	26.18				0.24
(25.71)		(1.19)	(8.31)				
			Panel C: Dependent variable – C^{ob}				
2.69			0.18	-0.13	0.15	-0.05	0.77
(9.56)			(0.07)	(0.06)	(0.06)	(0.03)	

Results from regressing the cost of managing the reserve account $C_i(y_{t+1})$ on financial profits fp_i, operating cost oc_i, checking accounts $check_i$ (thousands), and $region$. Liquidity and Non-performing loans (NPL) are defined in data appendix. The pooled regression pools uses the time series of excess reserves on the 19 banks.

Figure 1
Bank 6: Plot of $\ln y_{5t}$ vs. $\ln y^*_{5t}$

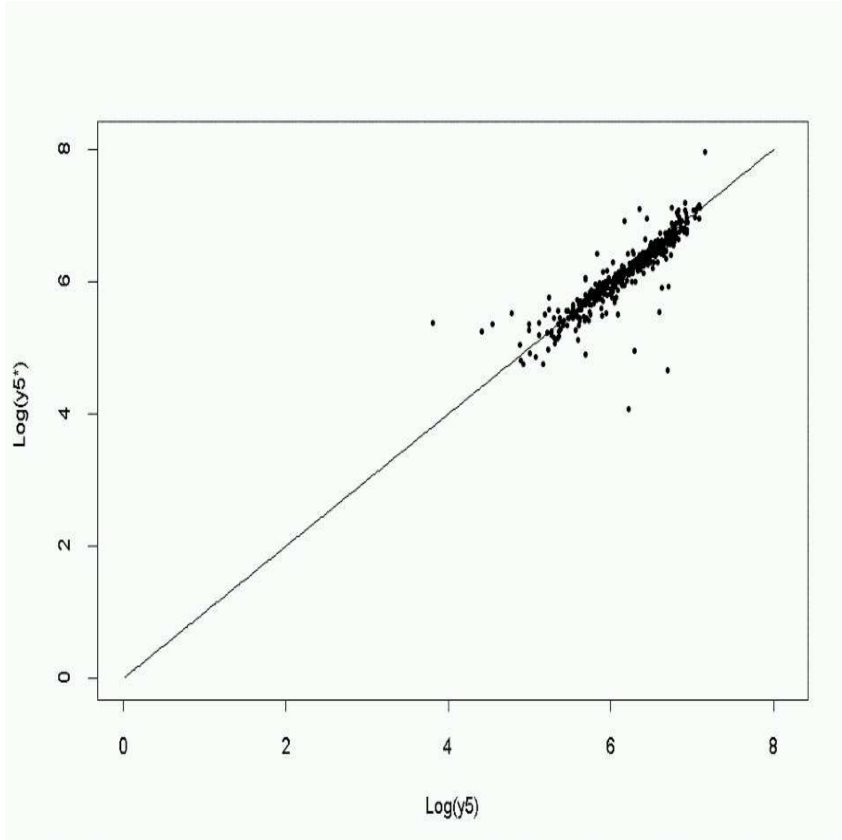

Figure 2
Bank 18: Plot of $\ln y_{5t}$ vs. $\ln y^*_{5t}$