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THE TIME-VARYING EFFECTS OF
MONETARY POLICY SHOCKS**

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ABSTRACT

Bank Loan Components and the Time-Varying Effects of Monetary Policy Shocks*

A robust finding for both small and large banks is that in response to a monetary tightening, real estate and consumer loans decrease while C&I loans increase. We also show that in a standard log-linear VAR the impulse response function of an aggregate variable is time-varying. The finding that loan components move in opposite directions and the property that the impulse response of total loans is time-varying explain why studies that use total loans have had such a hard time finding a robust response of bank loans to a monetary tightening.

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1 Introduction

Gertler and Gilchrist (1993) point out that conventional wisdom holds that a monetary tightening should be followed by a reduction in bank lending but that it has been surprisingly difficult to find convincing time-series evidence to support this basic prediction of economic theory. In this paper we find, both for small and for large banks, robust loan component (commercial and industrial (C&I) loans, real estate loans, and consumer loans) responses. This raises the question as to why no robust empirical evidence has been found for total loans. This paper provides two answers.

The first answer is that the components of total loans display different responses following a monetary tightening. In particular, whereas C&I loans significantly increase, real estate and consumer loans significantly decrease. Second, we show that if a vector autoregressive (VAR) model¹ contains the micro components of an aggregate variable then the responses of the aggregate variable will be time varying if the responses of the micro components are not identical. This is true even though the responses of these micro components do not vary across time.² Quantitatively this effect would be important if the relative magnitude of the micro components has changed over time, and this has indeed been the case for the bank loan components. Consequently we find that the responses of total loans display substantial time variation.

We analyze loan series for three bank categories. The first consists of all banks, the second of banks with assets above the 90th percentile, and the third of banks with assets below the 90th percentile. The responses for the loan components are, qualitatively, remarkably similar for both small and large banks, but there are some quantitative differences. Since the loan components do not move in the same direction, following a monetary contraction, these quantitative differences can imply that the size of the banks considered does matter for the sign of the response of total loans. We find that for small banks the response for total loans during the first three years (excluding the first quarter) is negative for all initial values, while for large banks the sign depends upon the initial conditions. For some initial values the total loan response for large banks is positive for all horizons, but for the majority of initial conditions we observe negative responses for several periods. Additionally, the responses of total loans for small banks are always below those for large banks.

Both for large and small banks we find that the increased importance of real estate loans in banks' loan portfolio means that the response for total loans has become more negative (less positive). In particular, for small banks we find that

¹This is the standard empirical model to study the effects of a monetary tightening.

²The reason is that a log-linear VAR is a simple, but nonlinear model of (the log of) total loans.

the responses have steadily become more negative after the early eighties. For large banks we observe a similar pattern and find that at several horizons where positive responses are observed early in the sample, negative responses are observed later in the sample.

In the econometrics literature there are many papers that deal with aggregation.³ These papers typically focus on the misspecification of the time-series model with aggregate variables and the efficiency of the estimation procedure. Moreover, typically linear frameworks are used.⁴ The focus of our paper differs from this literature. First, although our time-series model is very simple, it is nonlinear because the logarithms, not the levels of the variables, enter the VAR. Recall, that the logarithm of the aggregate variable is not the sum of the logarithms of the components, but is instead a nonlinear function of the components. In addition, we are mainly interested in the implication of our nonlinear setup—which is the standard one used in the literature—that the impulse response function of an aggregate variable is time varying.⁵

The rest of this paper is organized as follows. In Section 2 we explain why the impulse response function of a variable that is the sum of other variables in a log-linear system is time varying. Section 3 discusses the data used and the empirical methodology. Section 4 reports the results for the bank loan components, and Section 5 documents the time-varying responses of total loans implied by the estimated VAR with loan components. The last section concludes.

2 Time-varying impulse response functions

In this section we show that the impulse response functions of aggregate variables in disaggregated log-linear systems are, in general, time varying.⁶ In particular, the aggregate responses depend on the (relative) initial values of the micro components. These are, of course, stochastic and depend upon the history of shocks. We will see that even the shape and sign of the impulse response functions of aggregate variables can change over time. It is important to realize that the aggregate responses are time varying even though the coefficients of the VAR are constant and the impulse

³See, for example, Granger (1980) and Pesaran, Pierse, and Kumar (1989).

⁴An exception is van Garderen, Lee, and Pesaran (2000).

⁵See Potter (1999) for an overview of non-linear time-series models.

⁶The econometrics literature on the advantages and disadvantages of disaggregated models typically considers linear systems. In linear systems, the impulse response functions of aggregate variables would *not* be time varying. However, in practice, one typically uses log-linear systems to ensure that the effect of a shock, expressed as a percentage change, does not depend on the value of the variable.

response functions of the micro components are, thus, by construction not time varying.

To provide intuition we discuss a simple example in which we trace the behavior of an aggregate variable in response to a structural shock. The disaggregated system is as follows.

$$\ln(z_{1,t}) = \rho_1 \ln(z_{1,t-1}) + \sigma_1 e_t \quad (1a)$$

$$\ln(z_{2,t}) = \rho_2 \ln(z_{2,t-1}) + \sigma_2 e_t \quad (1b)$$

$$z_t = z_{1,t} + z_{2,t} \quad (1c)$$

Here $z_{1,t}$ and $z_{2,t}$ are the two micro components that add up to the aggregate variable z_t and e_t is a white noise structural error term with unit variance.⁷ We focus our analysis on the responses of the variables to changes in the structural shock e_t .

2.1 Dependence on initial values

To understand⁸ why the response of the aggregate variable is, in general, time varying consider the formula for the k -th period percentage change in z_t .

$$\begin{aligned} \frac{z_{t+k} - z_t}{z_t} &= \left(\frac{z_{1,t}}{z_t} \right) \left(\frac{z_{1,t+k} - z_{1,t}}{z_{1,t}} \right) + \left(\frac{z_{2,t}}{z_t} \right) \left(\frac{z_{2,t+k} - z_{2,t}}{z_{2,t}} \right) \\ &= \left(\frac{z_{1,t}}{z_t} \right) \widehat{z}_{1,k} + \left(\frac{z_{2,t}}{z_t} \right) \widehat{z}_{2,k} \end{aligned} \quad (2)$$

Thus, the percentage change in z_t is a weighted average of the percentage change in $z_{1,t}$ and the percentage change in $z_{2,t}$. The magnitude of the percentage changes in $z_{1,t}$ and $z_{2,t}$, in response to a change in the structural shock, are not time varying. In contrast, the weights depend on the relative size of $z_{1,t}$ and $z_{2,t}$ and are, thus, in general, time varying, which implies that the percentage change in z_t is also time varying. The only exception to this occurs when the laws of motion for $z_{1,t}$ and $z_{2,t}$ are identical.

To illustrate the time-varying nature of the impulse response functions of z_t we will focus on the case where $\rho_2 = \sigma_2 = 0$. Equation 1b then becomes

$$\ln(z_{2,t}) = 0. \quad (3)$$

⁷We assume that $|\rho_1| < 1$ and $|\rho_2| < 1$.

⁸We use the formula relating the percentage change of z_t to the percentage changes of $z_{1,t}$ and $z_{2,t}$ because it is simpler than the corresponding relationship for log changes. The latter would be the appropriate expression, since our log-linear system implies that changes in $\ln(z_{1,t})$ and $\ln(z_{2,t})$ are constant, not that the true percentage changes are constant.

The value of $z_{1,t}$ relative to $z_{2,t}$ is then simply the value of $z_{1,t}$ and the impulse response function of z_t varies with the value of $z_{1,t}$. To document this dependence we plot, in Figure 2.1, the response of $\ln(z_t)$ to a one standard deviation shock to e_t for five initial values of $\ln(z_{1,t})$. The initial values range from two times the unconditional standard deviation of $\ln(z_{1,t})$ below the unconditional mean to two times the unconditional standard deviation above the mean. For low values of $\ln(z_{1,t})$ the response of z_t to a shock is low because the effect on z_t is dominated by the zero effect on $z_{2,t}$. For high values of $\ln(z_{1,t})$ the response of z_t is large because the effect on z_t is dominated by the strong effect on $z_{1,t}$. Even the shape of the impulse response function varies with the initial value of $z_{1,t}$. In response to the shock, the value of $z_{1,t}$ increases relative to the value of $z_{2,t}$. When $z_{1,t}$ is large this does not matter much since the movements of z_t are dominated by the behavior of $z_{1,t}$. Consequently, for high values of $z_{1,t}$ we get an impulse response function for z_t that is similar to the impulse response function of $z_{1,t}$.⁹ When $z_{1,t}$ is small, however, $z_{1,t}$ increases relative to $z_{2,t}$, meaning that changes in $z_{1,t}$ will become more important for movements in z_t in the periods following the shock. The figure shows that this effect can be so strong that the percentage change in the aggregate variable is initially increasing even though the percentage change in $z_{1,t}$ is (by construction) monotonically decreasing.

2.2 Effects of the first and a subsequent shock

Since the response of the aggregate variable depends upon the relative size of the micro components, the effect of a subsequent shock in e_t will have a different effect than the initial shock. In the example from this section, in which the responses of the micro components are non-negative (and not equal), a subsequent positive shock of equal magnitude will have a larger effect. The reason for this is that a positive shock will increase the relative magnitude of the more sensitive component, $z_{1,t}$, and this increase in $z_{1,t}$ causes the effect of a shock on z_t to increase. We demonstrate this effect by doing the following. First we calculate the impulse response function of z_t using some initial conditions for $z_{1,t}$. Next we calculate the impulse response function of z_t using, as initial conditions, the values of $z_{1,t}$ observed in the period after the first shock. This second impulse response function, thus, does not measure the total effect of the two shocks but only the additional effect of the second shock.

In this exercise we use two different values for $z_{1,t}$ at the time of the first shock. In particular, we consider values of $\ln(z_{1,t})$ that are equal to two standard deviations below and above the mean. These are the two extremes of the five initial values considered in Figure 2.1. The results are presented in Figure 2.2. The figure shows

⁹Since $z_{1,t}$ is an AR(1) process its impulse response function monotonically declines to zero.

that when $z_{1,t}$ is already high relative to $z_{2,t}$, a further increase in $z_{1,t}$ in response to the first shock does not increase the sensitivity of z_t to the shock. Consequently, the effect of the second shock is only slightly bigger than the effect of the first shock. In contrast, when $z_{1,t}$ is low relative to $z_{2,t}$ the increase in $z_{1,t}$ strongly increases the sensitivity of z_t to the shock and the second shock will have a much bigger impact on z_t .

2.3 Relation to Wold decomposition

The aggregate variable z_t has a time-varying impulse response function because it is not a linear function of the two components and, therefore, is also not a linear function of the structural shock e_t . But, since it is a well-behaved stationary process, it consequently has a Wold decomposition. It is important to note that the (reduced-form) innovation of the Wold decomposition is not equal to the structural shock, and the impulse response function implied by the Wold decomposition is, in general, not equal to the impulse response functions for the structural shock. This is true even in an example like the one used here in which the structural shock is the only innovation in the system. That the impulse response functions are not equal is quite obvious since the impulse response function for the structural shock is time varying, while the impulse response function of the Wold decomposition is not. There is still, however, a link between the impulse response functions. The time-varying impulse response function for the structural shock represents the MA structure conditional on $z_{1,t}/z_{2,t}$ being equal to a certain value. The Wold decomposition gives the unconditional MA structure and, therefore, is the average value of the conditional time-varying impulse response functions.

2.4 Aggregate versus disaggregate systems

If one is interested only in the "average" effect of a shock one may simply want to estimate a time-series model for the aggregate variable and focus on the implied Wold decomposition. In this case, there are several things to be aware of. First, in practical applications there are several structural shocks, and the Wold decomposition would not only be an average across initial conditions, but also across different structural shocks. Second, simple disaggregated models can generate dynamics for aggregate variables that are quite complex.

For example, Granger (1980) shows that aggregation of AR processes can generate long memory. It is, thus, possible that many lagged terms are needed to accurately capture the dynamics of the aggregate process, but in practice one may not have enough data to accurately estimate many coefficients. That is, if one esti-

mates a univariate law of motion for the aggregate variable one could face a trade off between the potential misspecification of a low-order specification and the inaccurate estimation of a high-order specification.¹⁰ This second question is, of course, related to the question of whether there are advantages to using disaggregated time-series models even if one is only interested in the behavior of the aggregate time series. This question has already received a lot of attention in the literature¹¹ but is typically addressed using systems that are linear in the variables as opposed to the log-linear specification that is common in much applied work and used in this paper. Although it would be interesting to address the forecasting question in our log-linear framework we do not do so in this paper.

3 Empirical methodology

In Section 3.1 we discuss the data set employed in our study. Section 3.2 contains a discussion of our empirical methods.

3.1 Data

The loan data we use are from the Consolidated Reports of Condition and Income (Call Reports). For more information on how the data are constructed see Den Haan, Sumner, and Yamashiro (2002). In addition we use the federal funds rate, the consumer price index, and personal income from the Bureau of Economic Analysis (BEA).¹² The sample starts in the first quarter of 1977 and ends in the last quarter of 2000. More details on the data sources and definitions of the series are given in Appendix 7.1.

Small (large) banks are defined as those whose asset value is less (more) than the 90 percentile. As is well known, the largest banks have a disproportionately large share of assets. This is also true for the three loan components. Moreover, the relative importance of the top 10 percentile of banks has grown over time, as is documented in Tables 1 and 2.

Figure 3.1 plots the year-to-year growth rate for both small and large banks for the three loan components. The figure shows that there are substantial differences between large and small banks. To document this in more detail, Table 3 displays

¹⁰On the other hand, there are circumstances when it is advantageous to estimate a time-series process for the aggregate variable. For example, this is appropriate if there is a negative covariance between the innovations to the micro components.

¹¹See for example Pesaran, Pierse, and Kumar (1989) and Pesaran (2003).

¹²We use the income measure from the BEA because it is also available at the state level and we consider regional models in related work.

standard time-series statistics for the growth rate of the three loan components. Additionally, the figure makes clear that there have been large swings in the series. The credit crunch of the early nineties¹³ is visible in all series except the real estate loan series for small banks. For C&I loans this credit crunch was an extraordinary episode, but for the other loan series other large swings are observed over the sample period.

Figure 3.2 plots, for large and small banks, the relative importance of the three loan components in banks' loan portfolio. The graph shows that since the early eighties both small and large banks have increased the share of real estate lending in their portfolio. Small and large banks have offset the increased share of real estate lending in different ways. Large banks have decreased the share of C&I loans, while small banks have decreased the share of consumer loans in their portfolio.

Loan type	Large banks	Small banks
C&I	83%	17%
Real estate	67%	33%
consumer	65%	35%

Table 1: Relative importance of large and small banks; 1977:I

Loan type	Large banks	Small banks
C&I	91%	9%
Real estate	82%	18%
consumer	89%	11%

Table 2: Relative importance of large and small banks; 2000:IV

	C&I		Real estate		Consumer	
	Large	Small	Large	Small	Large	Small
Average	0.0174	0.0106	0.0268	0.0187	0.0191	0.0032
Standard deviation	0.0244	0.0207	0.0157	0.0131	0.0288	0.0207
Autocorrelation	0.20	0.52	0.55	0.63	0.26	0.44

Table 3: Summary statistics

¹³See Bernanke and Lown (1991).

3.2 Empirical methodology

In Sections 3.2.1 and 3.2.2 we show how we estimate the behavior of the variables during a monetary downturn and a non-monetary downturn of the same magnitude, respectively.

3.2.1 Monetary downturn

The standard procedure to study the impact of monetary policy on economic variables is to estimate a structural VAR using a limited set of variables. Consider the following VAR:¹⁴

$$Z_t = B_1 Z_{t-1} + \dots + B_q Z_{t-q} + u_t, \quad (4)$$

where $Z'_t = [X'_{1t}, r_t, X'_{2t}]$, X_{1t} is a $(k_1 \times 1)$ vector with elements whose contemporaneous values are in the information set of the central bank, r_t is the federal funds rate, X_{2t} is a $(k_2 \times 1)$ vector with elements whose contemporaneous values are not in the information set of the central bank, and u_t is a $(k \times 1)$ vector of residual terms with $k = k_1 + 1 + k_2$. We assume that all lagged values are in the information set of the central bank. In order to proceed one has to assume that there is a relationship between the reduced-form error terms, u_t , and the fundamental or structural shocks to the economy, ε_t . We assume that this relationship is given by:

$$u_t = \bar{A} \varepsilon_t, \quad (5)$$

where \bar{A} is a $(k \times k)$ matrix of coefficients and ε_t is a $(k \times 1)$ vector of fundamental uncorrelated shocks, each with a unit standard deviation. Thus,

$$E[u_t u'_t] = \bar{A} \bar{A}'. \quad (6)$$

When we replace $E[u_t u'_t]$ by its sample analogue, we obtain $n(n+1)/2$ conditions on the coefficients in \bar{A} . Since \bar{A} has n^2 elements, $n(n-1)/2$ additional restrictions are needed to estimate all elements of \bar{A} . A standard practice is to obtain the additional $n(n-1)/2$ restrictions by assuming that \bar{A} is a lower-triangular matrix. Christiano, Eichenbaum, and Evans (1999), however, show that to determine the effects of a monetary policy shock one can work with the less-restrictive assumption that \bar{A} has the following *block*-triangular structure:

¹⁴To simplify the discussion we do not display constants, trend terms, or seasonal dummies that may also be included.

$$\bar{A} = \begin{bmatrix} \bar{A}_{11} & 0_{k_1 \times 1} & 0_{k_1 \times k_2} \\ \bar{A}_{21} & \bar{A}_{22} & 0_{1 \times k_2} \\ \bar{A}_{31} & \bar{A}_{32} & \bar{A}_{33} \end{bmatrix} \quad (7)$$

where \bar{A}_{11} is a $(k_1 \times k_1)$ matrix, \bar{A}_{21} is a $(1 \times k_1)$ matrix, \bar{A}_{31} is a $(k_2 \times k_1)$ matrix, \bar{A}_{22} is a (1×1) matrix, \bar{A}_{32} is a $(k_2 \times 1)$ matrix, \bar{A}_{33} is a $(k_2 \times k_2)$ matrix, and $0_{i \times j}$ is a $(i \times j)$ matrix with zero elements. Note that this structure is consistent with the assumption made above about the information set of the central bank.

We follow Bernanke and Blinder (1992) and many others by assuming that the federal funds rate is the relevant policy instrument and that innovations in the federal funds rate represent innovations in monetary policy. Moreover, throughout this paper we assume that X_{1t} is empty and that all other elements are, therefore, in X_{2t} . Intuitively, X_{1t} being empty means that the Board of Governors of the Federal Reserve (FED) does not respond to contemporaneous innovations in any of the variables of the system. While we do believe that the FED can respond quite quickly to new information one has to keep in mind that the data used here are revised data, which means that the value of a period t observation in our data set was not available to the FED in period t . Rudebusch (1998) points out that if the econometrician assumes that the FED responds to innovations in the contemporaneous values of the available original data, but estimates the VAR with revised data, the estimated coefficients will be subject to bias and inconsistency. For these reasons, we believe it is better to assume that X_{1t} is empty.

3.2.2 Non-monetary downturn

Den Haan, Sumner, and Yamashiro (2004) compare the behavior of the variables during a monetary downturn, that is, the responses to a negative monetary policy shock with the behavior of the variables during a non-monetary downturn, that is, the responses during a downturn of equal magnitude caused by real activity shocks. To be more precise, a non-monetary downturn is caused by a sequence of output shocks such that output follows the exact same path as it does during a monetary downturn.

The motivation for looking at these impulse response functions is the following. The impulse response functions for the monetary downturn not only reflects the direct responses of the variables to an increase in the interest rate but also the indirect responses to changes in the other variables and, in particular, to the decline in real activity. This makes it difficult to understand what is happening, especially since a decline in real activity could either increase or decrease the demand for bank

loans.¹⁵ For example, if one observes an increase in a loan component during a monetary downturn it could still be the case that there is a credit crunch if a decline in real activity strongly increases the demand for that particular loan component. Without the credit crunch this loan component would have increased by even more. By comparing the behavior of loan components during a monetary downturn with a non-monetary downturn, of equal magnitude, one can get an idea regarding the importance of the different effects.

Den Haan, Sumner, and Yamashiro (2004) argue that the comparison of the behavior of loans to monetary policy shocks and output shocks is useful in understanding what happens during the monetary transmission mechanism. In this paper, the comparison is used to address two questions. First, we want to understand whether the differences in the behavior of the loan components, between the two downturns, that Den Haan, Sumner, and Yamashiro (2004) found for all banks, is similar when one differentiates banks by size. Second, the impulse response function for the non-monetary downturn is still simply an impulse response function, and when calculated for total loans will in principle be time varying. So this will provide another application to study the quantitative importance of time-varying impulse response functions for aggregate variables.

Implementing this exercise requires us to make an additional assumption on \bar{A} . In particular, we assume that shocks to real activity have no contemporaneous effect on any of the other variables.¹⁶ Under this assumption, there is a simple way to calculate the impulse response functions. In each period one simply sets the value of aggregate real activity equal to the value observed during the monetary downturn, and one can then obtain values for the remaining variables by iterating on the VAR.¹⁷ We can interpret the difference between the impulse response functions during a monetary downturn and during a non-monetary downturn as the effect of the increase in the interest rate holding real activity constant.¹⁸

The construction of a non-monetary downturn makes it convenient to quan-

¹⁵The reduction in real activity would reduce investment and, thus, the need for loans, but the reduction in sales would increase inventories, which could increase the demand for loans.

¹⁶That is, the matrix \bar{A}_{33} also has a block-triangular structure. Note that the block-triangular structure imposed in Equation 7 already made the assumption that the innovation to output had no effect on the federal funds rate.

¹⁷The assumption that shocks to real activity do not affect the other variables contemporaneously implies that we do not have to explicitly calculate the values of the structural shocks during a non-monetary downturn. It is possible to make other assumptions on \bar{A} and still calculate the impulse response functions, but it would be slightly more cumbersome.

¹⁸In fact, the difference between these two impulse response functions is equal to the response to a shock in the federal funds rate when the response of the output variable is set equal to zero in every period.

titatively compare the responses, but one would obtain similar results by simply comparing the responses to a monetary policy shock with the responses to a *single* output shock.

4 Responses of loan components

The results discussed in this section are based on a VAR that includes the three loan components in addition to the federal funds rate, a price index, and a real activity measure. Our benchmark specification for the VAR includes one year of lagged variables, a constant, and a linear trend. We also include quarterly dummies since the data from the Call reports are not adjusted for seasonality.¹⁹

Figure 4.1 plots the responses for output, the price level, and the federal funds rate. The results are consistent with those in the literature. Output declines, but with a delay and only reaches its maximum decline after two years. The federal funds rate gradually moves back to its pre-shock value, with half of this adjustment occurring in the first year or so. In contrast, in response to the output shocks, interest rates decline, which is consistent with the monetary authority following a Taylor rule. Consequently, during a non-monetary downturn interest rates fall, but note that quantitatively the decline is quite moderate. Finally, our results are subject to the price puzzle, with the price level increasing after a monetary tightening.²⁰

Figure 4.2 reports the behavior of the three loan components during a monetary and a non-monetary downturn using the series for all banks. The graph shows that there are important differences between the behavior of the three loan series after a monetary tightening. Both real estate loans and consumer loans display sharp negative decreases, although there is some delay before both begin to fall. In

¹⁹In addition, we estimated VARs for which the specification was chosen using the Bayes Information Criterion (BIC). We search for the best model among a set of models that allows, as regressors, the variables mentioned above and a quadratic deterministic trend. BIC chooses a specification that is more concise than our benchmark specification. The results are similar to those that are based on our benchmark specification and are available upon request.

²⁰Christiano, Eichenbaum, Evans (1999) find that adding an index for sensitive commodity prices solves the price puzzle in their sample, but we find that this does not resolve the puzzle for our more recent samples. We also tried the measure of monetary policy shocks proposed by Romer and Romer (2004) and reestimated the VAR over the period for which this measure is available (1977 - 1996). We find that the price level sharply increases during the first two quarters and after roughly one year has returned to its original level after which it hovers around zero. Although not a solution to the price puzzle it is an improvement, since when we use innovations in the federal funds rate as the monetary policy shock, the price level displays a persistent increase to a monetary tightening. More importantly, however, is that our other results are robust when using this alternative measure.

contrast, C&I loans immediately increase and are significantly positive for several years. Den Haan, Sumner, and Yamashiro (2004) provide arguments related to hedging and banks safeguarding their capital adequacy ratio that can explain these movements. Here we take the responses as given and analyze what they imply for the response of total loans.

The responses to the loan components during a non-monetary downturn gives a very different picture. First, note that real estate loans decrease (not a statistically significant decrease though), but not by as much as they do during a monetary downturn. Consumer loans are little changed. Thus, the behavior of real estate and consumer loans is consistent with the view that a monetary tightening reduces the supply of bank loans by more than is predicted by the decline in real activity. In contrast, C&I loans decrease during a non-monetary downturn.

In Figures 4.3 and 4.4 we plot the responses of the three loan components for large banks (top 10 percentile) and small banks (bottom 90 percentile).²¹ In Section 3.1 we showed that there were substantial differences in the time-series behavior of the loan series for small and large banks and that the relative importance of large banks had grown over time. Given these differences it is remarkable that the behavior of the loan components during both a monetary and a non-monetary downturn are so similar.²² In particular, for both large and small banks we observe that the responses for real estate and consumer loans decrease during a monetary downturn, and not (or less) during a non-monetary downturn. Similarly, C&I loans increase during a monetary downturn and decrease during a non-monetary downturn. There are some intriguing quantitative differences, however. For example, the response of real estate loans is larger for small banks than it is for large banks. The opposite is true for consumer loans.

5 Time-varying responses of total loans

In Section 2 we showed that the impulse response function of a variable that is the sum of variables in the VAR will, in general, be time varying. We can expect this to be more of an issue when (i) the responses of the micro components differ and (ii) their relative magnitudes change over the sample. In Section 3.1 we showed that the relative magnitudes of loan components changed substantially over time both for

²¹The responses for output, the federal funds rate, and the price level are similar to those in Figure 4.1 and are not reported.

²²Kashyap and Stein (1995) find more substantial differences between the responses for large and small banks in their specifications that do not control for changes in real activity. When they do control for changes in real activity the differences are strongly reduced.

large and for small banks and in Section 4 we documented that C&I loans respond quite differently to monetary policy shocks than real estate and consumer loans.

To see how important the variation in initial conditions across the sample are, we calculate the impulse response function for total loans for all observed initial values of the loan components. The results are plotted in Figure 5.1, 5.2, and 5.3 for all banks, large banks, and small banks, respectively. In each figure, Panel A plots the response of total loans to a shock in the federal funds rate and Panel B plots the difference between the response of total loans during a monetary downturn and a non-monetary downturn. The figures show that there is indeed substantial variation in the response of total loans, especially for large banks and especially for the series that measures the difference between the monetary and the non-monetary downturn. In particular, for large banks there are initial conditions such that the total loan responses are positive for all time horizons, while there are initial conditions such that the response is negative for several periods. For small banks the responses are (at least in the first three years) consistently negative. Nevertheless, even for small banks we find important quantitative differences. In particular, for the 8th period response the largest decrease of 4.76% is more than twice as large as the smallest decrease of 2.38%.

The total loan responses for all banks are, at first, always positive and only become negative after more than a year has passed. In contrast, the total loan responses for small banks become negative in the second quarter and are clearly below the responses for large banks.²³ Whereas the responses of the loan components displayed robust and significant responses to a monetary tightening (but not in the same direction), the responses of total loans—with the exception of the response for small banks—hover around zero in the first couple of years. So, to some extent, the responses of total loans give an incomplete picture of what happens to bank lending during a monetary tightening.

We also compared the responses of total loans discussed above, which are based on a VAR with loan components, with the response of total loans that are based on a VAR that does not disaggregate total loans into its components. Of course, the response of total loans from the latter would not be time varying. We find that for small banks the response of total loans is similar to the average of the time-varying responses. For the large bank and all banks series, however, the response is a bit above the time-varying responses.²⁴

The figures discussed above do not make clear which impulse response function

²³This is consistent with the results of Kashyap and Stein (1995).

²⁴Given that the impulse responses of the loan components are actually estimated fairly precisely, the reason is likely to be that the simple VAR, without loan components, has a hard time capturing the dynamics of the system with only a relatively small number of lags.

corresponds to what set of initial conditions. In Figure 5.4 we make this clear by plotting, for each period, the response eight quarters after the shock using as initial conditions the observed values of the loan components in that period. The patterns are similar for both small and large banks, but as mentioned above the response for small banks is below the response for large banks. We can expect the response of an aggregate variable to decrease over time if the variable with the response that is less negative becomes smaller over time. That is true in our case since the fraction of C&I loans has decreased over time and the response of C&I loans is, not only, less negative, it is positive. We see that the responses for total loans indeed decrease over time although the results are not monotone. The eight-quarter responses for total loans increase in the beginning of the sample and reaches its maximum in the early eighties before a steady decline sets in. For small banks the smallest value is observed in the early nineties after which the results stabilize. For large banks a minor increase is observed during the nineties. To analyze the statistical significance of the amount of time variation we checked whether the difference between the response observed in the first quarter of 1983 (when the most positive value for large banks is observed) and the response in the last quarter of the sample is significantly different from zero. For all three loans series we find that the difference is significant at the 5% level.²⁵

6 Concluding Comments

The time-varying responses reported in this paper are from a VAR with constant coefficients. Although the specifications used include a deterministic trend term, the question arises as to whether the coefficients of the VAR remain the same when the relative magnitudes of the loan components display such substantial changes. It might very well be that the observed changes in the relative magnitudes of the loan components correspond with changes in how banks respond to shocks. It is even a logical possibility that banks behave in such a way to keep the response of total loans to monetary policy shocks constant when the relative magnitude of the loan components change. In this case, it might be better to actually use a VAR that only includes total loans.

Obviously one always has to be aware of the possibility that behavior changes over time. The main point of this paper is that impulse response functions of aggregated variables can change over time *even if* the behavior of the micro components does not change over time. In this paper we have demonstrated that this is a quantitatively important phenomenon for total loans.

²⁵In each Monte Carlo replication of our bootstrap procedure we calculated this difference and we checked whether the 5% percentile was positive.

7 Appendix

7.1 Data sources and definitions

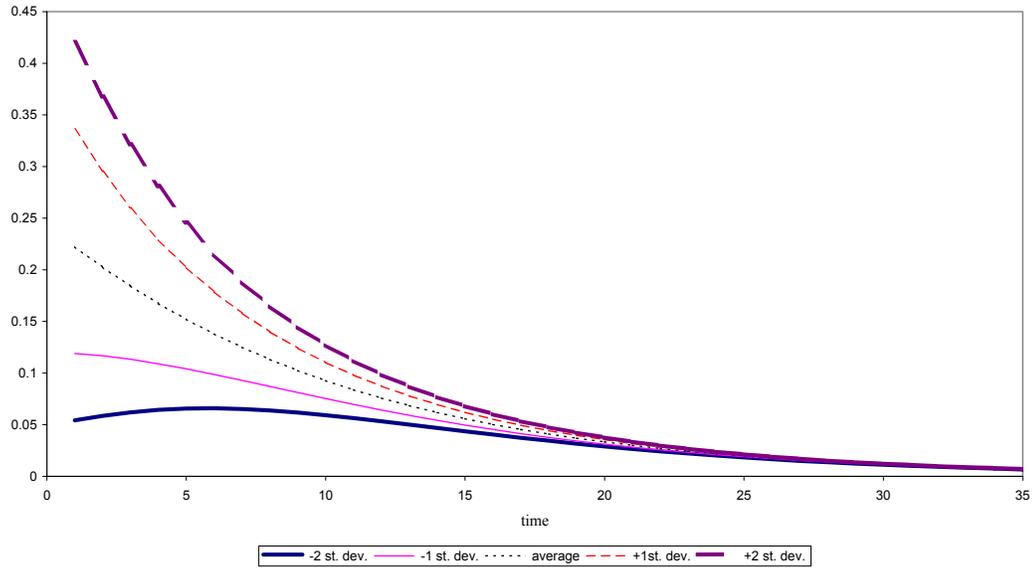
Bank balance-sheet data are available at <http://faculty.london.edu/wdenhaan> and a description on how they are constructed can be found in Den Haan, Sumner, and Yamashiro (2002). In this paper we use the "level series". Quarterly observations for the CPI and federal funds rate are constructed by taking an average of the monthly observations downloaded from <http://research.stlouisfed.org> (CPI) and <http://www.federalreserve.gov> (federal funds rate), respectively. The income variable used is earnings (by place of work) from the Bureau of Economic Analysis. It was downloaded from <http://www.bea.doc.gov/>. In related work we examine the effect of regional responses to monetary policy shocks and the advantage of this real activity measure is that it is available at the regional level. The results are very similar, however, if we use GDP and its deflator.

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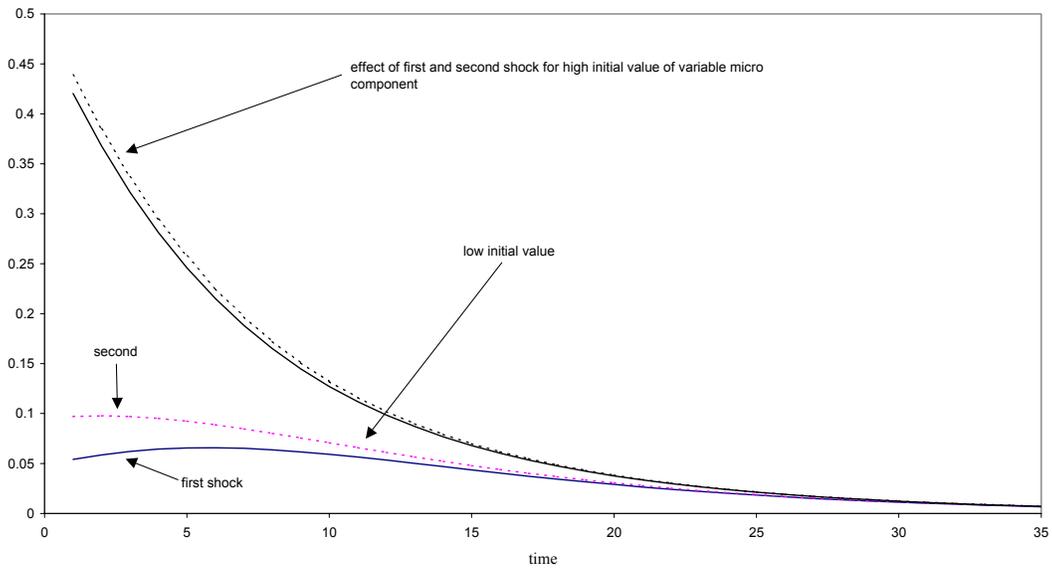
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Figure 2.1: Impulse response function of z_t for different initial values of $\ln(z_{1,t}/z_{2,t})$



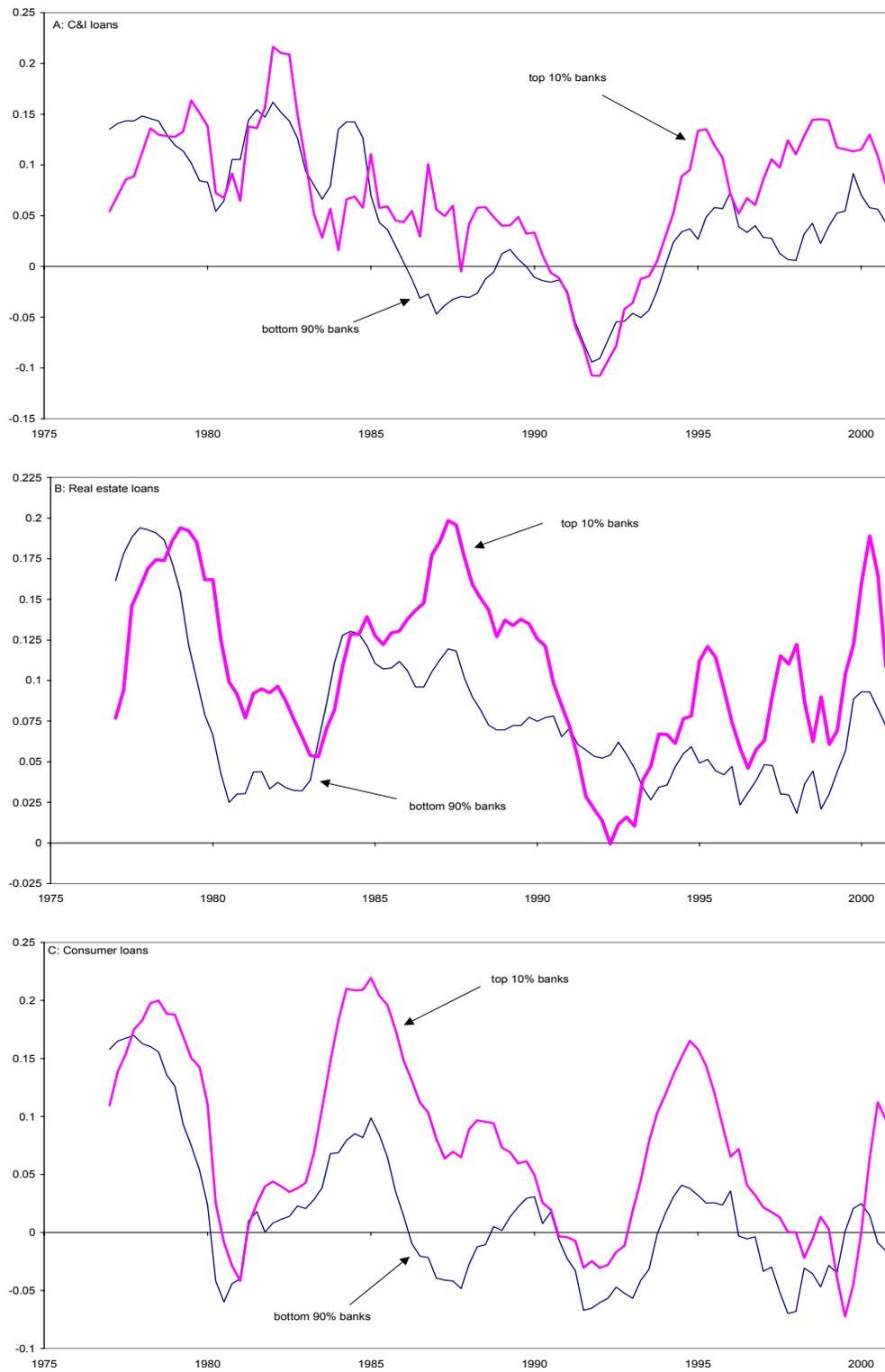
Note: This graph plots the impulse response function of $\ln(z_t)$ in response to a one-standard-deviation shock in e_t when the value of $\ln(z_{1,t}/z_{2,t})$ varies from being two standard deviations below to two standard deviations above its average value (of zero)

Figure 2.2: Impulse response function of z_t for first and second shock



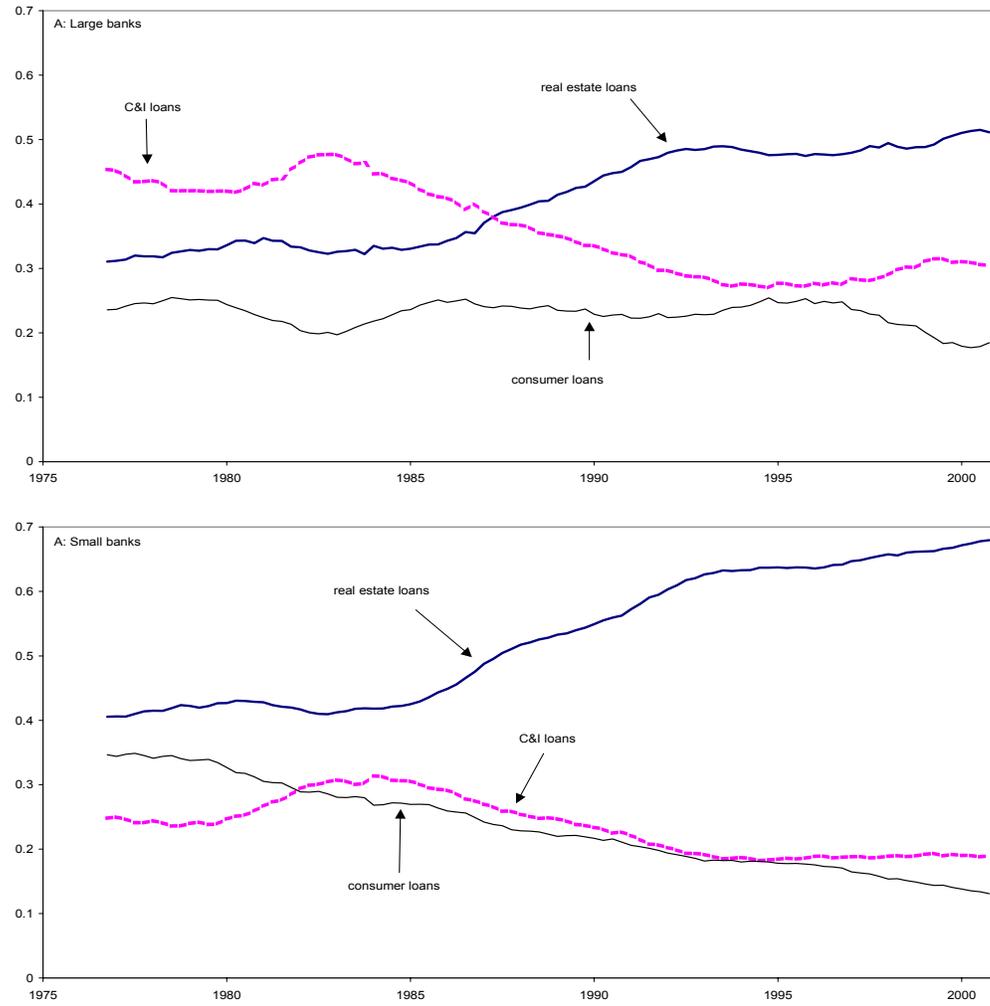
Note: This graph plots the impulse response function of $\ln(z_t)$ in response to a one-standard-deviation shock in e_t (solid line) and the impulse response function of $\ln(z_t)$ in response to a subsequent shock of equal magnitude (dashed line) when the value of $\ln(z_{1,t}/z_{2,t})$ at the time of the first shock occurs is equal to two standard deviations below (low initial value) and two standard deviations above its average value (high initial value).

Figure 3.1: Loan components for large and small banks



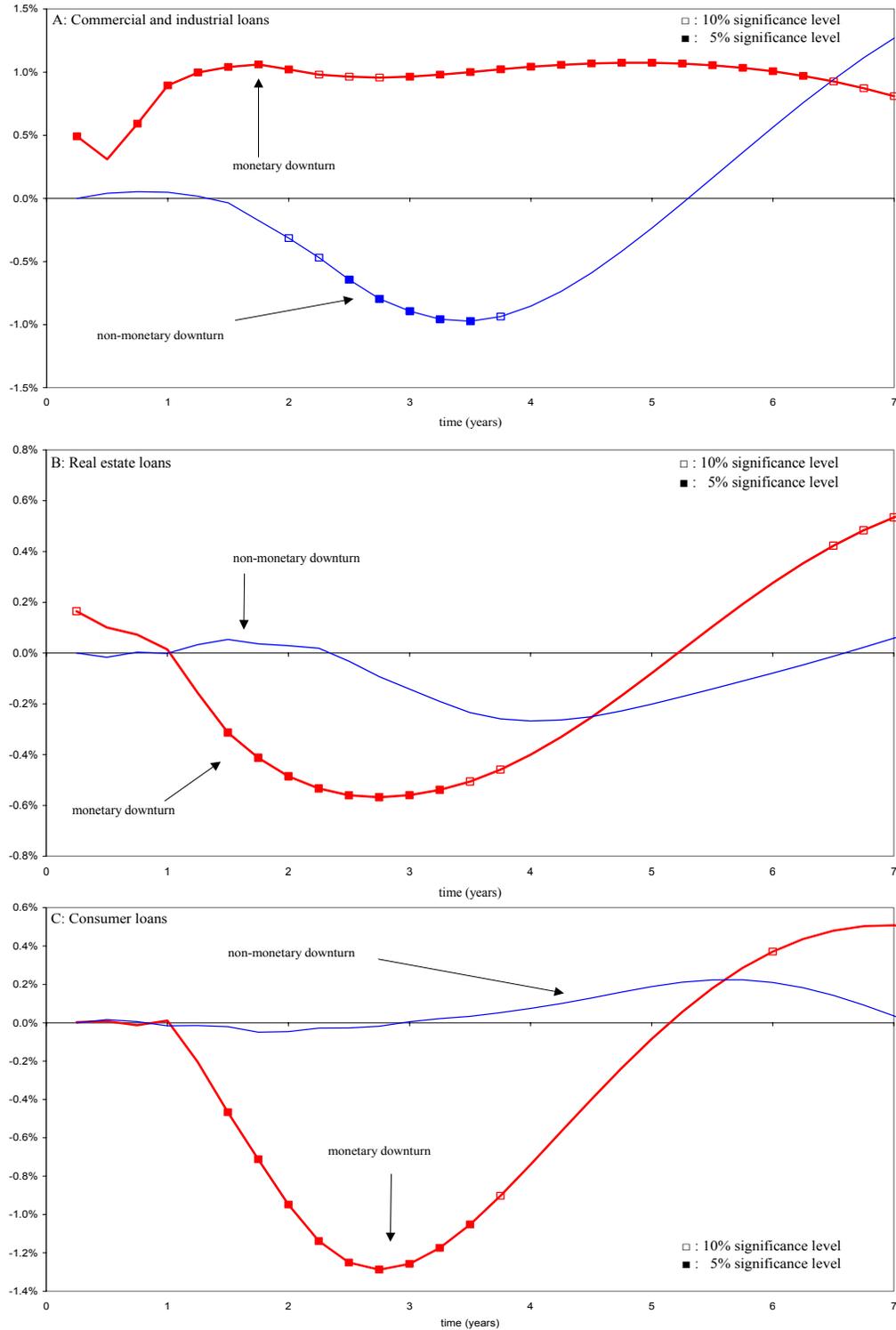
Note: These graphs plot for each quarter the natural log growth rate over the past year.

Figure 3.2: Banks' loan portfolio



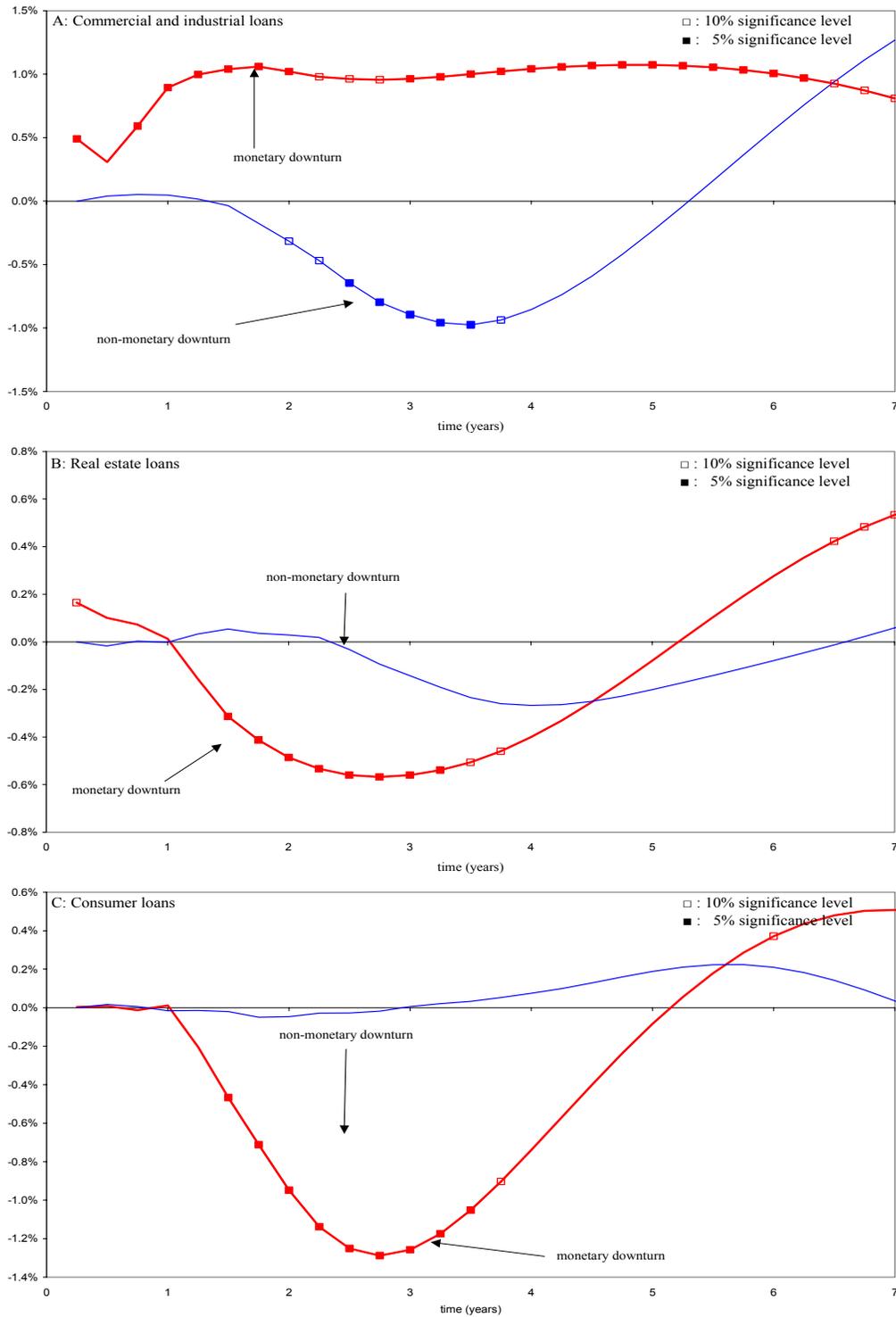
Note: These graphs plot the share of the indicated loan component as a fraction of the sum of the three loan components.

Figure 4.1: Impulse responses for output, price level, and federal funds rate (VAR with “all bank” loan series)



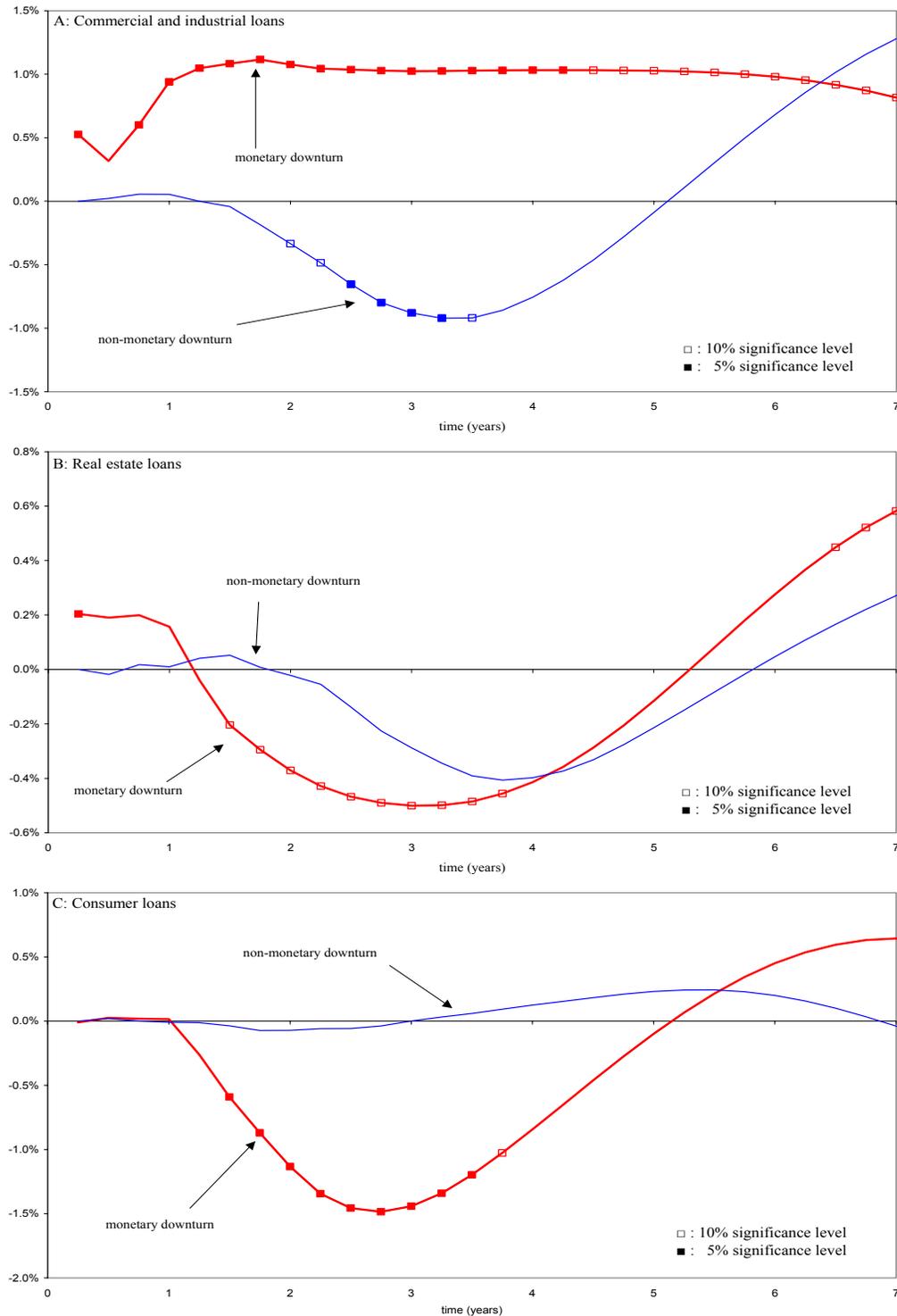
Note: These graphs plot the response of the indicated variable to a one-standard deviation shock to the federal funds rate, i.e., a monetary downturn. In Panels B and C the curve labelled “non-monetary downturn” plots the time path of the federal funds rate and consumer price index following a sequence of output shocks that generates a time path for output that is identical to that of the monetary downturn plotted in panel A. The results are based on the benchmark specification. Open squares indicate a significant response at the 10% level and a solid square indicates a significant response at the 5% level (both one-sided tests).

Figure 4.2: Loan impulse responses - All banks



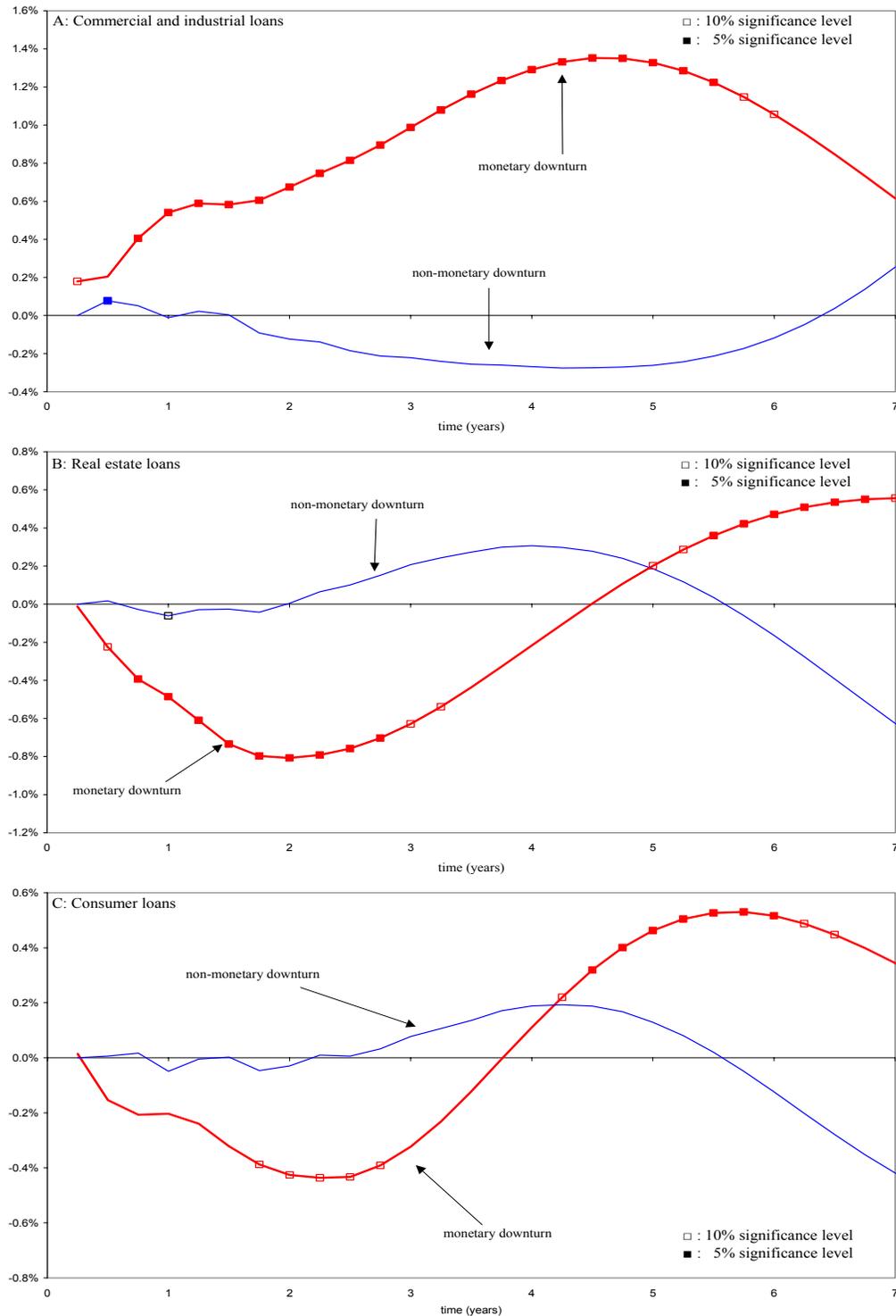
Note: These graphs plot the response of the indicated loan variable to a one-standard deviation shock to the federal funds rate, i.e., a monetary downturn. The curves labelled “non-monetary downturn” plot the time path of the loan variable following a sequence of output shocks that generates a time path for output that is identical to that of the monetary downturn (plotted in panel A of Figure 4.1). The results are based on the benchmark specification. Open squares indicate a significant response at the 10% level and a solid square indicates a significant response at the 5% level (both one-sided tests).

Figure 4.3: Loan impulse responses - Large banks



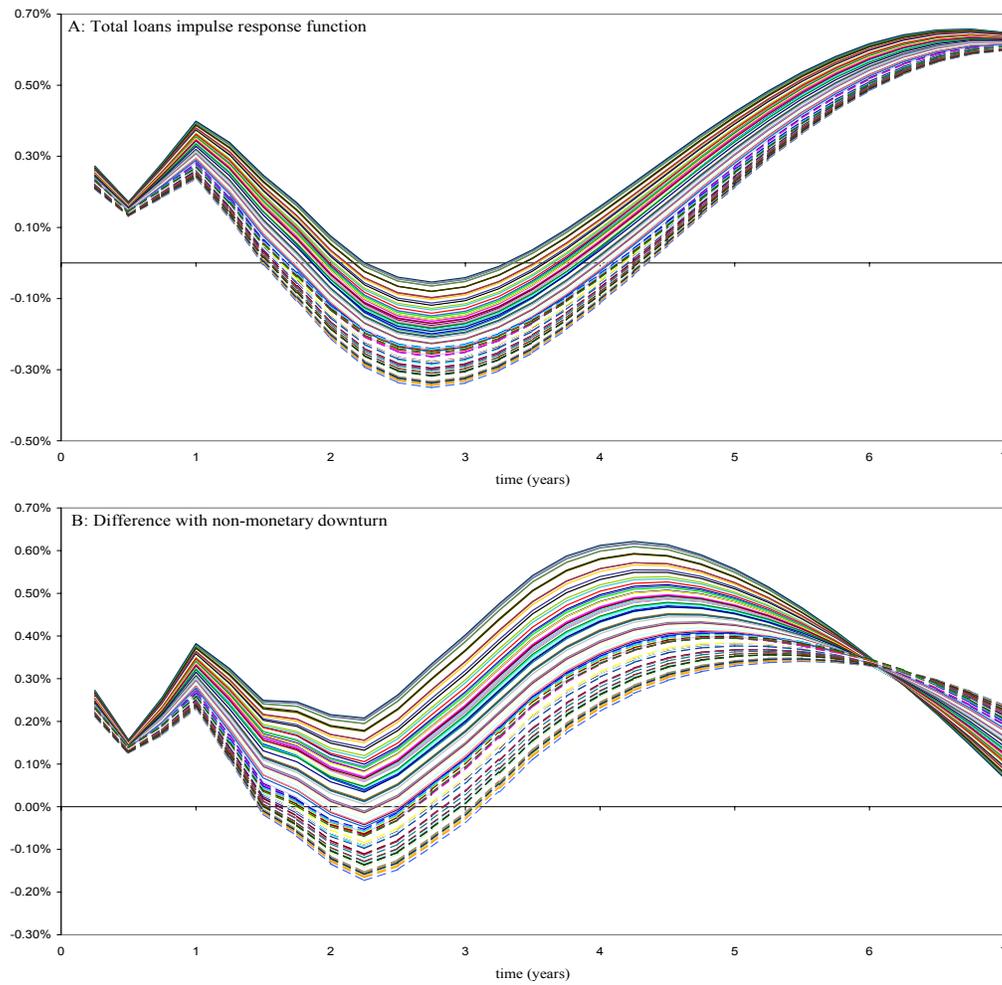
Note: These graphs plot the response of the indicated loan variable to a one-standard deviation shock to the federal funds rate, i.e., a monetary downturn. The curves labelled “non-monetary downturn” plot the time path of the loan variable following a sequence of output shocks that generates a time path for output that is identical to that of the monetary downturn. The results are based on the benchmark specification. Open squares indicate a significant response at the 10% level and a solid square indicates a significant response at the 5% level (both one-sided tests).

Figure 4.4: Loan impulse responses - Small banks



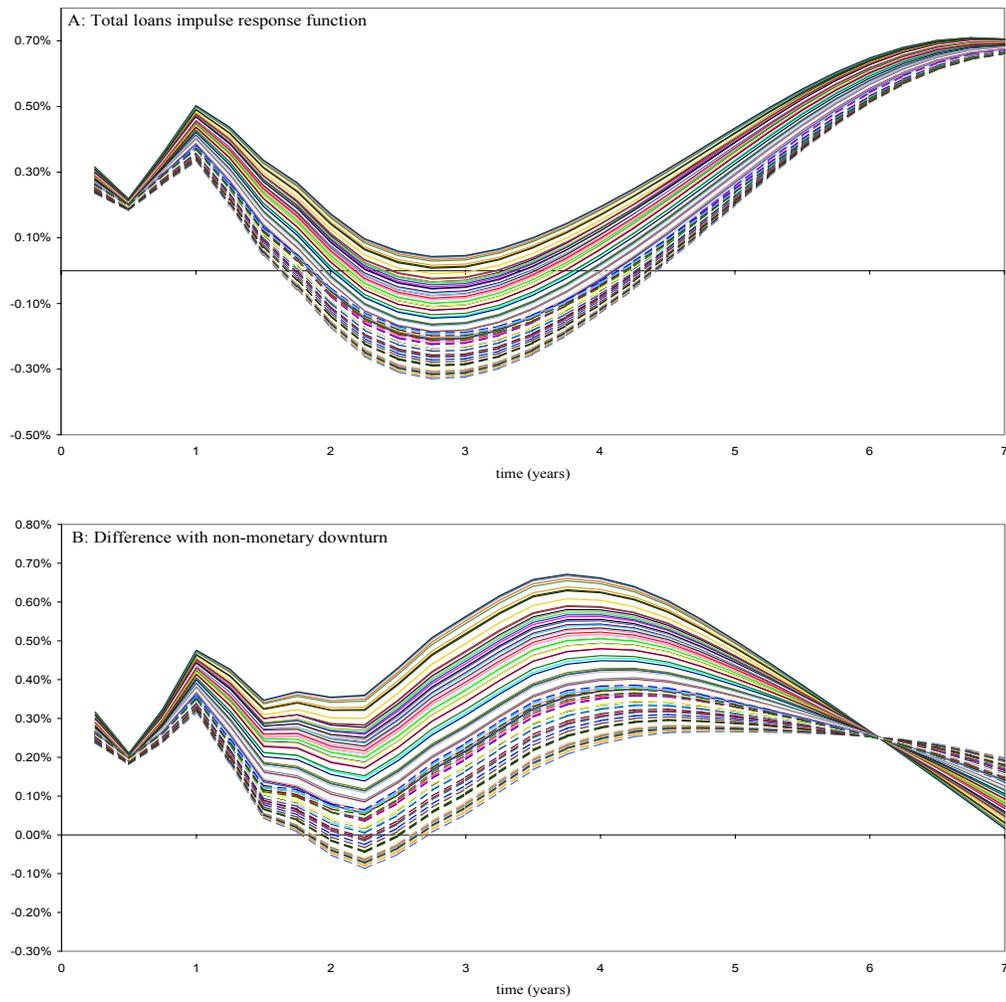
Note: These graphs plot the response of the indicated loan variable to a one-standard deviation shock to the federal funds rate, i.e., a monetary downturn. The curves labelled “non-monetary downturn” plot the time path of the loan variable following a sequence of output shocks that generates a time path for output that is identical to that of the monetary downturn. The results are based on the benchmark specification. Open squares indicate a significant response at the 10% level and a solid square indicates a significant response at the 5% level (both one-sided tests).

Figure 5.1: Total loans impulses for VAR with loan components - All banks



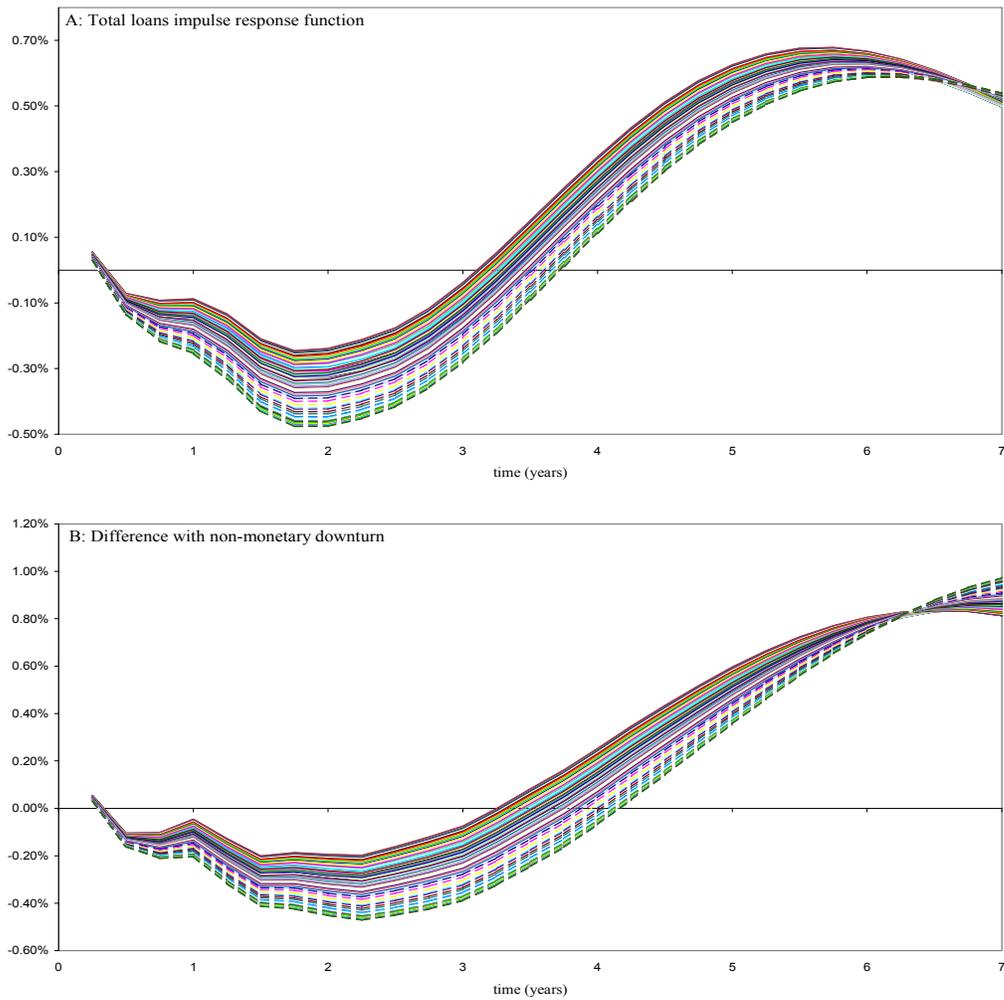
Note: Panel A plots the impulse response function of total loans for all initial conditions observed in the sample. Panel B plots the difference between the response of total loans during a monetary downturn and a non-monetary downturn.

Figure 5.2: Total loans impulses for VAR with loan components - Large banks



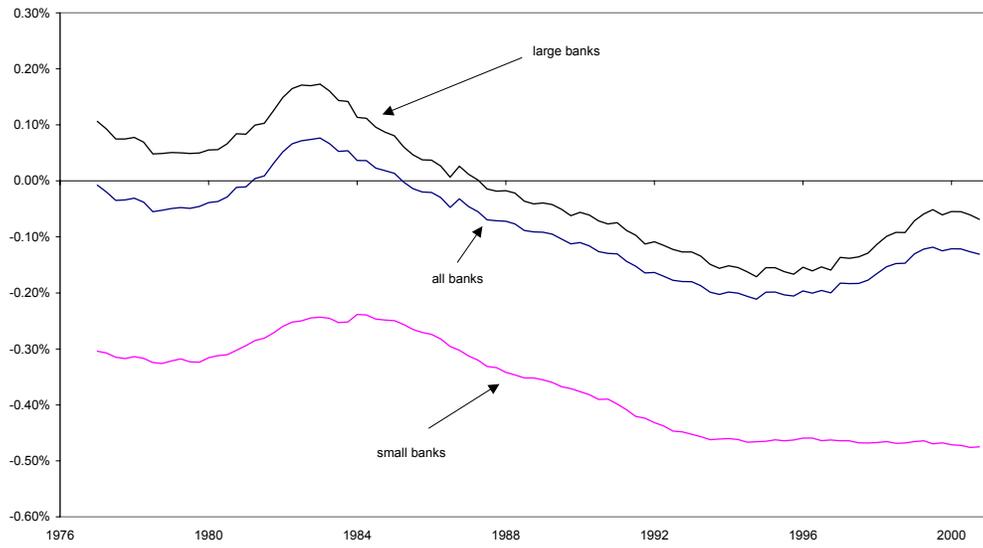
Note: Panel A plots the impulse response function of total loans for all initial conditions observed in the sample. Panel B plots the difference between the response of total loans during a monetary downturn and a non-monetary downturn.

Figure 5.3: Total loans impulses for VAR with loan components - Small banks



Note: Panel A plots the impulse response function of total loans for all initial conditions observed in the sample. Panel B plots the difference between the response of total loans during a monetary downturn and a non-monetary downturn.

Figure 5.4: eight-quarter total bank loans response for VAR



Note: This graph plots the 8-quarter impulse response of indicated total loans series using as initial values those observed in the period indicated on the x-axis.