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Asymmetries in Bank Lending Behaviour. Austria During the 1990s

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Editorial

In this paper Sylvia Kaufmann investigates both cross-sectional asymmetry (related to bank-specific characteristics like size and liquidity) and asymmetries over time (potentially related to the overall state of the economy) in Austrian bank lending reaction to monetary policy. The first type of asymmetry is accounted for by including interaction terms, and the second type is captured by latent state-dependent parameters. Estimation is cast into a Bayesian framework, and the posterior inference is obtained using Markov chain Monte Carlo simulation methods. The results document a significant asymmetric effect of interest rate changes over time on bank lending. During economic recovery, lagged interest rate changes have no significant effect on lending. Where the effects are significant, liquidity emerges as the bank characteristic that determines cross-sectional asymmetry.

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Asymmetries in bank lending behaviour. Austria during the 1990s.

Sylvia Kaufmann [1]

November, 2001

Abstract

This paper investigates both cross-sectional asymmetry (related to bank-specific characteristics like size and liquidity) and asymmetries over time (potentially related to the overall state of the economy) in Austrian bank lending reaction to monetary policy. The first type of asymmetry is accounted for by including interaction terms, and the second type is captured by latent state-dependent parameters. Estimation is cast into a Bayesian framework, and the posterior inference is obtained using Markov chain Monte Carlo simulation methods. The results document a significant asymmetric effect of interest rate changes over time on bank lending. During economic recovery, lagged interest rate changes have no significant effect on lending. Where the effects are significant, liquidity emerges as the bank characteristic that determines cross-sectional asymmetry.

Keywords: Asymmetry, bank lending, Markov switching, Markov chain Monte Carlo.
JEL classification: C11, C23, E51.

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1 Introduction/Economic motivation

In addition to the cross-sectional differences in the lending reaction of banks after a change in monetary policy that have been dealt with in a growing volume of theoretical and empirical literature, the present paper investigates a potential asymmetric response of bank lending over time, potentially related to the overall state of the economy. The papers by Bernanke and Blinder (1988, 1992), Christiano et al. (1996), Bernanke and Gertler (1995), Kashyap et al. (1993) certainly revived the interest in the subject by enlightening the "black box" that surrounds the transmission process of monetary policy. Kashyap and Stein (1995), and Stein (1998) on a more formal basis, go further and provide a microfoundation of the lending view, and as such the background model for the present paper. They show how the lending reaction differs among banks of different size and/or liquidity due to credit market imperfection. Agency costs make it more difficult for small and/or illiquid banks to obtain alternative (external) funding when a restrictive policy drains reserves.

In contrast, there is less literature on the time dimension of asymmetry in monetary policy transmission. Kiyotaki and Moore (1997) develop a model where debt repayment default leads to a credit crunch chain reaction that amplifies and makes more persistent the initial liquidity shock perturbing the system. Moreover, a chain reaction of default during a recession is more probable and exaggerates the response of the economy to liquidity shocks. The solution of the model presented in Azariadis and Smith (1998) yields time series properties that are explicitly described by a regime switching behaviour. Cyclical contractions involve declines in real interest rates, increases in credit rationing and withdrawals of savings from banks while periods of economic expansion display rising interest rates, with Walrasian equilibrium prevailing where credit is not rationed.

Empirical findings for the U.S. and selected European countries (e.g. Kashyap and Stein, 1995, de Bondt, 1999) document cross-sectional asymmetry in bank lending behaviour. Kashyap and Stein obtain their evidence by first aggregating bank data into size classes and then estimating a time series process for each class. De Bondt displays results on six EU countries using a panel data set for each country covering the first half of the 1990s. Specific investigations using bank panel data with a longer time dimension or including additional country-specific features produce additional evidence on a bank lending channel in European countries (see Loupias et al., Hernando and Martínez-Pagès, Brissimis et al., Farinha and Robalo Marques, Gambacorta, de Haan, Topi and Vilmunen, Worms, all 2001).

In the same line of research, this paper presents evidence on Austrian banks, supplemented by initial evidence on an asymmetric effect of monetary policy that may be at work over time. Evidence on time asymmetry has been investigated on an aggregate level only so far. An explicit Markov switching specification is adopted in Garcia and Schaller (1995), Kakes (1998), and Kaufmann (2001). They all find monetary policy to have different effects on the real economy depending on the phase of the business cycle. The potential asymmetry over time is captured by state-dependent parameters, where the latent state variable switches between regimes that prevail during periods of different length. The latent specification accounts for the fact that the overall (relevant) state of the economy is usually not observed with certainty. The state variable itself follows a Markov switching process, which accounts for the different length of the regimes. The use of Markov switching models in economics was initially promoted by Hamilton (1989, 1990). The application of such models within a panel data context is presented in Asea and Blomberg (1997), where the asymmetric pricing of new lending is estimated by means of maximum likelihood methods. Here, estimation is cast into a Bayesian framework instead. The inference is performed using Markov chain Monte Carlo (MCMC) simulation methods, applying in particular the permutation sampler derived in Frühwirth-Schnatter (2001). The Bayesian approach used in the present paper circumvents problems that tend to arise when Markov switching models are estimated by standard maximum likelihood methods. Moreover, it is well known that within the maximum likelihood context it is not possible to test for the null of K versus $K+1$ states within a standard classical context, as the likelihood ratio test statistic departs from the χ^2 distribution given unidentified parameters under the null. The Bayesian approach allows to test various models against each other by means of the marginal (or model) likelihood, i.e. by means of the Bayes factor.

The present paper investigates a panel of quarterly individual bank data covering the period 1990/1 to 1998/2. The first difference of the 3-month Austrian interest rate is used as a measure for monetary policy. The results document a significant asymmetric effect of monetary policy over time, irrespective of the model specification for total loans and loans to firms including alternatively various interaction terms. In terms of marginal likelihood, the specification including liquidity as a bank-specific characteristic performs best in capturing cross-sectional asymmetry in bank lending reaction. The evidence reveals that state 1 prevails during the period of economic recovery that is identified to have begun in the second quarter of 1993 and to have lasted through the end of the observation period. The effect of lagged interest rate changes is muted during these periods. This result can be explained by the specific feature of the Austrian banking sector, which mostly consists of small banks doing local business supplying a full spectrum of financial services and maintaining tight customer relationships. State 2 prevails at the beginning of the sample through half of the mild slowdown lasting through the first quarter of 1993. Interest rate changes have a (positive) significant effect on bank lending in this state (which is also the case in the linear model), with this accommodative reaction being larger for banks with an above-average liquidity share. Again, we might explain this counterintuitive result with the willingness of banks to provide financing support during periods of tight liquidity.

The next section provides an initial look at the data to characterize the structure of the Austrian banking sector. It also summarizes the macroeconomic background of the analysis, and comments on the data cleaning. First evidence on cross-sectional asymmetry in total bank lending and lending to firms is presented in section 3. Section 4 then introduces asymmetry over time into the model and presents results on a linear, and alternatively, on a nonlinear, latent state specification. Section 5 concludes. Appendices A and B reproduce the sampling scheme along with the prior specifications and the identification procedure of state-specific parameters in the latent state model specification, respectively.

2 A first look at the data

2.1 Structure of the banking sector

At the end of 2000, 934 banks were operating in Austria, of which 130 had been newly founded during the 1990s. These 130 banks and 5 additional ones with recorded liquidity shares above 100% are removed from the original data set as the analysis is performed with a balanced data set given computational restrictions. The retained 799 banks represent 82% of the banking market in terms of total assets, and they reflect some typical characteristics of the Austrian banking system as tabulated in table 1. Overall, three sectoral groupings dominate the market. The savings banks (*Sparkassen*) form the largest sector, accounting for of roughly 31% of lending to non-financial institutions. The *Sparkassen* are organized in a two-tier system, with *Erste Bank* serving as the central institution. Most savings bank are owned either by a municipality or a foundation. Publicly owned savings banks are, moreover, backed by a public guarantee which is underpinned and superseded by a mutual assistance obligation.

Mostly joint stock banks and the Postal Savings Bank (*Postsparkasse*) constitute the commercial banks' sector, which follows with a market share of 26%. The co-operatives' banking sector with a 25.7% market share consists of two bank groups, agricultural and industrial credit cooperatives (*Raiffeisenkassen* and *Volksbanken*, respectively). Most of the very small banks, where depositors are the shareholders, are

Table 1: Structure of the banking sector as of 1996 (first quarter), in million euro.

	No. of inst.	Assets (in % of total)	Loans (in % of total)
Joint stock and private banks	36	101257 (31.3)	40150 (26.1)
Sparkassen (savings banks)	68	97625 (30.2)	47487 (30.8)
Erste Bank (central inst.)	1	16953 (5.2)	7671 (5.0)
Raiffeisenkassen (agricult. credit coop.)	604	71665 (22.1)	30540 (19.8)
Raiffeisen Zentralbank (central inst.)	1	16785 (5.2)	5408 (3.5)
Raiffeisenlandesbanken (regional inst.)	8	20537 (6.3)	6330 (4.1)
Volksbanken (industrial credit coop.)	67	16139 (5.0)	8979 (5.8)
Oesterreichische Volksbanken AG	1	5262 (1.6)	2590 (1.7)
State mortgage banks and building societies	11	30857 (9.5)	23602 (15.3)
Other banks	13	6253 (1.9)	3310 (2.1)
Total	799	323797	154069

found in this last sector. The former group is characterized by a three-tier system with *Raiffeisen Zentralbank* and 8 *Raiffeisenlandesbanken* as central and regional institutions, respectively. *Oesterreichische Volksbanken AG* is the central institution of the two-tier *Volksbanken* sector. Typical business activities (as well as the business activities of the small savings banks) are restricted on a local area and focus on retail banking on a small to medium-sized scale. All inter-regional or large-scale financing lending or foreign exchange activities are channeled through the central or regional institutions. A mutual assistance arrangement similar to that of the savings banks' sector links the *Raiffeisen* banks and the *Volksbanken*.

State mortgage banks mainly do business in mortgages and issue mortgage bonds (*Pfandbriefe*) guaranteed by the respective state (*Bundesland*), while building societies (*Bausparkassen*) are used to channel subsidised savings into mortgages. Together, both groups reach a market share of 15%. Finally, other banks comprise special-purpose banks such as factoring companies or companies specialising in long-term or leasing financing. Their market share of 2% reaches a level of minor significance.

The different sectors and their activities reflect the economic needs at the time the system was installed in the nineteenth century, and the widespread public ownership

Table 2: Structure of the unadjusted balanced sample as of 1996, first quarter, in million euro. The 95% interval are measured using the 2.5th lower and upper percentiles, respectively.

	Total	big	small	big	small	liquid	illiquid
		>1601	<11	>97.5th	<50.0th	>95.0th	<50.0th
No of banks	799	32	29	21	400	41	400
Total assets	323,797	247,844	206	222,817	11,053	6,336	284,661
Market share		0.77	0.00	0.69	0.03	0.02	0.88
Median size	56	3563	8	4439	26	34	84
95% interval	9/2,859	1,841/46,084	1/11	2,859/46,084	7/53	2/1,272	12/4,223
Med. liquidity	19.30	9.89	23.06	7.78	22.39	38.06	14.44
95% interval	3.9/38.0	1.8/31.3	11.2/34.2	1.8/19.1	11.5/38.1	33.4/50.5	1.8/19.1
Total loans/ Market share	154,069	0.74	0.00	0.65	0.04	0.01	0.89
Med. loan share	53.83	56.22	50.38	56.16	50.62	37.80	56.95
95% interval	21.4/78.0	24.0/86.3	23.5/76.6	26.8/86.3	25.3/77.9	4.4/54.7	13.9/81.9

is due to the lack of strong private investors in the post World War II reconstruction period. However, partly due to the intensive merger activity during the 1990s[2], the distinctions between the sectors are becoming blurred, in particular the one between commercial and savings banks. The first cross-sector merger took place in 1991, when the *Länderbank* merged with *Zentralsparkasse* after having encountered financial difficulties to form *Bank Austria*, a savings bank. *Bank Austria* thus became the largest bank in Austria ahead of *Creditanstalt*. In 1997 the federal government sold its stake in *Creditanstalt*, a commercial bank, to *Bank Austria*. While both banks continue to operate under separate corporate identities in the domestic market, their activities abroad were merged. At the same time, *Erste Bank* (formerly *Erste SparCasse*) was newly established, and became the second largest bank by fully integrating *GiroCredit*, the former central institution of the *Sparkassen* sector. Most of the 182 mergers (where 268 banks were overtaken), however, involved small banks. In particular, 118 mergers took place in the *Raiffeisenkassen* sector, followed by 30 and 18 mergers in the *Sparkassen* and the *Volksbanken* sector, respectively.

Table 2 summarizes the statistical properties of the pooled data set and characterises the distributional features of the variables used subsequently in the analysis. Loans comprise loans to non-financial enterprises and households, and the liquidity (share) is equal to the sum of cash, short-term interbank deposits and government securities divided by total assets. A bank is classified as being large (small) in absolute value if its total assets exceed 1.6 billion euro. Under this criterion 32 banks accounting

[2]Triggered to improve efficiency and diversify into new business segments, see Mooslechner (1989, 1995) and Waschiczek (1999).

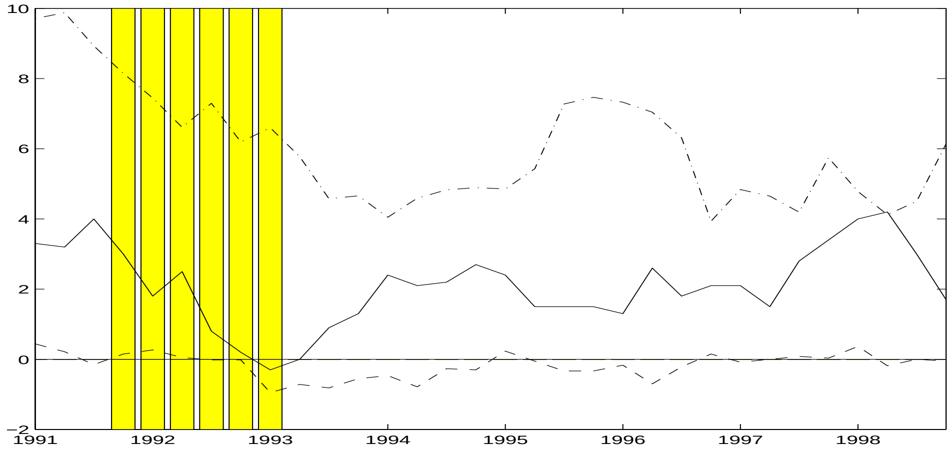
for over 75% of Austrian banking assets qualify as large. In contrast, the smallest banks' share does not amount to a significant part of the banking sector. The top 21 banks cover nearly 70% of the banking market, which is not that much for a small EU country. Even the top five banks' market share is not higher than 50%. On the other hand, more than half of the banks reach only a minor share in the banking sector, reflecting the fact that the Austrian banking sector is dominated by very small banks. The last two columns of this first panel classify the banks according to their relative liquidity, revealing in particular, that the liquid banks tend to be smaller on average than the illiquid ones. Finally, the 95% interval of total assets, computed by using the lower and upper 2.5th percentiles, is in general larger for big and illiquid banks than for small and liquid ones. The next panel on liquidity corroborates the statement just made, where again, liquidity shares vary much more among big banks than between small banks. The third panel on loans and loan shares finally, reveals that the distribution of the loan market reproduces the distribution of total assets. Interestingly, the median loan share of big banks is not very different from the one of small banks, whereas loan shares vary again more across big than across small banks. It is not easy to form expectations on the bank lending channel given the typical features of the Austrian banking market just discussed. With the Austrian market dominated by small banks that do business primarily on a local scale, and with their ownership structure, Austrian banks tend to face smaller informational problems. Moreover, the multi-tier system alleviates banks' exposure to liquidity constraints during periods of restrictive monetary policy. What follows is that the size of a bank might not be decisive for its lending reaction to monetary policy moves. A feature that is linked with the predominance of small banks doing business locally is the emergence of a "housebank" system, with firms or households relying on a single bank to effect most of their financial and financing transactions. These tight customer relationships also apply to large banks as they, too, offer the whole spectrum of financial services to their customers. To reinforce these relationships, banks may well be willing to insulate their customers from the full effects of tight monetary policy. Thus, monetary policy effects might be muted and as such not observable in the lending reaction of banks.[3]

2.2 Macroeconomic background and aggregate loan behaviour

A further look at the macroeconomic background along with the lending behaviour at the aggregate level yields an additional indication about the kind of results that may be obtained. Figure 1 depicts yearly GDP growth rates (dyr, computed by summing

[3]See also Ehrmann et al. (2001)

Figure 1: Main aggregates: annual GDP growth rates (solid, computed by summing four log differences), annual loans growth rates (dashed-dotted, year-on-year quarterly growth rates), and lagged interest rate changes (dashed, first difference of the interest rate). The shaded area identifies the recession period at the beginning of the 1990s



the quarterly growth rates) along with the lagged change in the Austrian 3-month interest rate (dir_{t-1}), and yearly loans growth rates (as year on year quarterly growth rates). The shaded area refers to the recession period that affected European countries at the beginning of the 1990s but that turned out to be quite mild in Austria. No official business cycle dating is available for Austria. Therefore, the turning points are identified here by visual inspection of figure 1, and the third quarter of 1991 and the first quarter of 1993 are identified as the peak and the trough of the cycle. Note that for Germany, the major trading partner of Austria, the respective peak and trough of the business cycle, in particular the first quarter of 1991 and the fourth quarter of 1994[4], identify a longer cyclical downturn. For the rest of the observation period, the Austrian economy was performing quite well, with the recovery gaining a strong momentum particularly in 1997.

The main interest rate changes occurred during the first half of the 1990s. Lasting interest rate rises are observable through the first half year of 1992. Afterwards, interest rates were broadly declining throughout the observation period. The last rise of nearly 37 bps is registered for the first quarter of 1998, followed by a decrease of 18 bps in the next quarter, however. By the time monetary union was established, interest rate moves had ceased to be significant, with the decline being 5 bps and nearly 7 bps in the last two quarters of 1998, respectively. On the aggregate level, loans can be observed to have largely fallen through 1994, with some hikes during the cyclical downturn. In 1995/1996, during the second round of declining interest

[4]These turning points are identified by the Economic Cycle Research Institute (www.businesscycle.com).

Table 3: Correlations between quaterly and annual loans growth rates with interest rate changes (lagged once and twice), and with GDP growth (lagged once and twice).

	sample period: 1991:Q1 – 1998:Q4					
loans, quarterly growth rates	1.00					
loans, yearly growth rates	0.28	1.00				
interest rate changes, lagged once	-0.07	0.13	1.00			
interest rate changes, lagged twice	0.13	0.36	0.57	1.00		
GDP growth rate	-0.29	-0.19	-0.01	-0.10	1.00	
GDP growth rate, lagged once	0.09	-0.00	0.29	0.10	-0.03	1.00
	sample period: 1993:Q2 – 1998:Q4					
loans, quarterly growth rates	1.00					
loans, yearly growth rates	0.28	1.00				
interest rate changes, lagged once	-0.36	-0.21	1.00			
interest rate changes, lagged twice	0.05	-0.05	0.59	1.00		
GDP growth rate	-0.30	0-0.05	0.07	0.07	1.00	
GDP growth rate, lagged once	-0.16	-0.12	0.24	0.27	-0.05	1.00

rates, loans' growth rates transitorily rose again to above 7%.

Table 3 summarizes the correlations between these three main aggregates. Over the whole observation period, the correlation between the quarterly loan growth rates and lagged interest rate changes is negative but very small (if not insignificant). Yearly growth rates of loans are positively correlated with lagged interest rate changes, contrary to what we would expect normally. Note that the correlation increases between the loan growth rates and interest rate changes lagged twice. The picture changes when the observation period is restricted to the recovery phase beginning in the second quarter of 1993. Interest rate changes become negatively correlated with quarterly and yearly loan growth rates, while the correlations with interest rate changes lagged twice are very small. During this period, the expected effects of monetary policy should be observable. However, the results are obviously driven by the second major decline in interest rates occurring in 1995/1996 accompanied by a contemporaneous rise in loan growth rates. Throughout the recovery period, we do not have observations for the opposite case, in which a rise in interest rates leads to a decline in bank lending. The following analysis using a panel data set will assess whether monetary policy actions (interest rate changes) have a negative effect on bank lending, at least, as suggested by the simple correlations, during the recovery period. Moreover, the results are thought to reveal additionally whether cross-sectional asymmetries (and of which type) in bank lending reaction were at work during the observation period.

Interestingly, GDP is negatively correlated to the loan growth rates. Besides just reproducing the characteristics of the observation period, GDP growth rates might reflect the demand situation the banking sector faces. Above-average growth rates might induce a decrease in loan demand as during these periods firms can rely more heavily on internal funds (e.g. retained earnings) rather than bank debt, and both firms and households are paying off their debts.

2.3 Data cleaning/data compilation

The analysis is performed with quarterly data running from 1990/1 through 1998/2. They are compiled from the monthly bank statements reported to the Oesterreichische Nationalbank by each individual bank. The initial sample covers all banks present at the end of the observation period. The compilation of the data treats mergers in such a way that accounts of banks involved in a merger are consolidated and subsequently reported under the absorbing bank. Thus, banks that were absorbed are not in the original sample anymore. This procedure yields time series of relevant balance sheet items, in particular the loans and the size series used in the present investigation, that display breaks around periods when mergers took place.

As mentioned before, the investigation is done for a balanced sample, so that only banks will be included for which data on the relevant variables are available for the whole sample period. Outliers are identified in several steps. First, the loan series of banks involved in a merger are inspected visually. As expected, this generally reveals an extreme value in the loan growth rate and a break in the total assets series recorded for the period coinciding with the merger. Second, for each bank separately, "true" outliers are identified as observations lying outside the interval of +/-5 times the interquartile range around the median of the loan growth rate. These outliers could be treated as missing values to be estimated by extending the sampler described in the appendix by one step (a procedure pursued in Frühwirth-Schnatter and Kaufmann, 2001). However, size is an exogenous variable, and there is no way to account for the break present in this series. Therefore, all banks involved in a merger or having some outliers in their series have to be removed from the sample.

Finally, the first screening of the data also revealed some banks with very volatile loans series that did not display the usual pattern of most other banks. These banks turned out to be mostly specialised leasing or foreign banks. The first group specialises in leasing contracts (mainly car financing), so their lending is mainly related to the launch of new car series or changes is fiscal regimes. Specialised foreign banks' business activity (mainly trade finance business) on the other hand, might depend more heavily on the international financial situation or on the financial situation faced by the head office abroad rather than on Austrian monetary policy. Therefore, these banks are also removed from the sample without incurring too much information loss.

This leaves us with a total of 665 banks covering approximately 50% of the Austrian banking sector over the whole observation period. While a lot of information may be expected to have been lost through this very strict cleaning process, the distribution of the adjusted balanced sample in fact nearly reproduces the distribution of the original, unadjusted balanced sample summarized in table 2. Two other facts justify the belief that the strict cleaning does not introduce an information bias into the data. First, including the merging banks would amount to including sound institutions that were able to take over other banks, and hence were less prone to liquidity constraints enhanced by monetary policy changes. Second, the analysis in Frühwirth-Schnatter and Kaufmann (2001) uses the full balanced panel data set, and the results of the pooled model therein led to a qualitatively similar inference as here.

For the analysis the variables were transformed in the following way. The growth rate of loans (100 times the first difference of the logarithmic level) represents the dependent variable. For comparison, the equation is estimated for loans to firms as these are potentially the ones granted without collateral.[5] The size of a bank is measured by the logarithm of total assets. As mentioned before, the liquidity share is equal to the sum of cash, short-term interbank deposits and government securities divided by total assets. Due to changing reporting definitions, this series displays a break at the end of 1995 which is accounted for by a dummy variable. Accordingly, lish95 will denote the liquidity share up to 1995, and lish96 the liquidity share from 1996 on. As a measure for monetary policy we use the first difference of the 3-month Austrian interest rate. The investigation period begins in the second quarter of 1990 and is restricted to end by the second quarter of 1998 in order to include the second largest bank (*Creditanstalt AG*) in the sample. Its series of the asset total has a break in the third quarter of 1998 as the bank was overtaken at the time by the largest Austrian bank (*Bank Austria AG*, see previous subsection). Finally, note that each bank characteristic and the two-way interaction between size and liquidity are transformed to deviations from the mean within the cross-section in each quarter in order for the coefficients to have the direct interpretation of the monetary policy effect (see footnote 7).

3 Cross-sectional asymmetry in bank lending

Some initial evidence on the bank lending channel is obtained by estimating a loan supply function that takes into account bank-specific differences in lending reaction

[5] Due to the significant changes in variables definitions at the end of 1995, a further breakdown of loans is not sensible because consistent time series are not feasible.

to monetary policy actions.[6] To this aim, the growth rate of loans (dlo) is regressed on lagged first differences of the Austrian 3-month interest rate (dir). In view of the exchange rate regime that pegged the Austrian schilling to the German mark throughout the observation period, the use of the domestic interest rate as a measure for monetary policy is justified by the correlation with the German interest rate being higher than 0.9 for the levels, and the first differences, too. The cross-sectional differences in the bank lending reaction are captured by interacting the first difference of the interest rate with bank-specific variables like size (si) and liquidity (lish95 and lish96). Real GDP growth (dyr) and the inflation rate (dp) are included to control for overall real and nominal loan demand growth, respectively. If dlo_{it} denotes the growth rate of loans of bank i in period t, $i = 1, \ldots, N$, $t = 1, \ldots, T$, the most general model reads:[7]

$$\begin{aligned}\mathrm{dlo}_{it} = \beta_{1,0} + \sum_{q=1}^{3} \beta_{1,q} D_{qt} + \beta_{1,4}\mathrm{dp}_t + \beta_{1,5}\mathrm{dyr}_t + \beta_{1,6}\mathrm{si}_{it-1} + \beta_{1,7}\mathrm{lish95}_{it-1} + \\ \beta_{1,8}\mathrm{lish96}_{it-1} + (\beta_{1,9}\mathrm{lish95}_{it-1} + \beta_{1,10}\mathrm{lish96}_{it-1}) \cdot \mathrm{si}_{it-1} + \sum_{q=1}^{r} \beta_{1,10+q}\mathrm{dlo}_{it-q} + \\ \sum_{q=1}^{p} (\beta_{2,1q}\mathrm{dir}_{t-q} + \beta_{2,2q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1}) + \beta_{2,3q}(\mathrm{dir}_{t-q} \cdot \mathrm{lish95}_{it-1}) + \\ \beta_{2,4q}(\mathrm{dir}_{t-q} \cdot \mathrm{lish96}_{it-1}) + \beta_{2,5q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1} \cdot \mathrm{lish95}_{it-1}) + \\ \beta_{2,6q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1} \cdot \mathrm{lish96}_{it-1})) + \varepsilon_{it}, \quad (1)\end{aligned}$$

where ε_{it} is i.i.d. $\mathcal{N}(0, \sigma^2)$ and D_{qt}, $q = 1, 2, 3$ are dummy variables to account for the seasonality in the data.[8] Estimates consistent with the bank lending view should report positive values for $\beta_{2,2q}$, $\beta_{2,3q}$, and $\beta_{2,4q}$. $\beta_{2,2q} > 0$ reflects the fact that larger banks have easier access to alternative (external) financing of their loan portfolio. $\beta_{2,3q}, \beta_{2,4q} > 0$ documents the ability of more liquid banks to draw down on their liquid assets to keep up their loan portfolio. In both cases, higher values of the individual bank characteristic attenuate the effect of monetary policy. The coefficient on the three-way interaction is expected to be negative, $\beta_{2,5q}, \beta_{2,6q} < 0$, as liquidity constraints are tighter for small banks.

Tables 4 and 5 report estimates of the relevant parameters for various specifications

[6] See also Ehrmann et al. (2001) in which the equation is explicitly derived, and where the specific assumptions to identify loan supply are stated.

[7] The direct monetary policy effect is estimated by $\beta_{2,1}$, if $\sum_{i=1}^{N} \mathrm{si}_{it-1} = 0$. If the bank characteristics are not demeaned, the mean effect of monetary policy on loans will depend on the average level of the variable, e.g. if only size is included: $\partial\overline{\mathrm{dlo}}_t / \partial\mathrm{dir}_{t-1} = \beta_{2,11} + \beta_{2,21} \cdot \frac{1}{N} \sum_{i=1}^{N} \mathrm{si}_{it-1}$. Therefore, size and liquidity as well as their interaction enter equation 1 as demeaned variables.

[8] Another possibility to account for seasonality is to compute year-on-year quarterly growth rates. The model estimates, however, remained qualitatively the same in terms of signs on coefficients and significance. Therefore, the estimates with dummy variables are presented here.

Table 4: Linear specification (with t-values) for total loans growth rates. The liquidity share is interacted with a dummy variable to account for the break in the level and the standard deviation of the series due to changing reporting definitions. The inference is based on the last 5,000 of 7,000 iterations of the permutation sampler described in appendix A, whereby step (i) and (ii) are dropped, and step (iii) and (iv) are adjusted to a one-state specification. The AR(1) and AR(2) statistics denote the percentage of banks that have remaining autocorrelation in the residuals at the 5% significance level.

	interest rate	with size	with liquidity	with size and liquidity
dir_{t-1}	0.28*	0.50*	0.50*	0.49*
	(2.43)	(5.42)	(5.43)	(5.30)
dir_{t-2}	-0.05			
	(-0.39)			
dir_{t-3}	0.59*			
	(4.52)			
sum	0.75*			
	(6.76)			
$\text{dir}_{t-1} \cdot \text{si}_{t-1}$		0.01		0.01
		(0.18)		(0.04)
$\text{dir}_{t-1} \cdot \text{lish95}_{t-1}$			0.00	-0.00
			(0.20)	(-0.04)
$\text{dir}_{t-1} \cdot \text{lish96}_{t-1}$			-0.01	-0.03
			(-0.19)	(-0.39)
$\text{dir}_{t-1} \cdot \text{si}_{t-1} \cdot \text{lish95}_{t-1}$				0.00
				(0.11)
$\text{dir}_{t-1} \cdot \text{si}_{t-1} \cdot \text{lish96}_{t-1}$				0.00
				(0.38)
log marginal likelihood	-48778.20	-48782.89	-48763.95	-48783.26
AR(1) significance at 5% level	0.07	0.07	0.07	0.07
AR(2) significance at 5% level	0.04	0.04	0.04	0.04

The AR test is based on the AC index, $A = \sqrt{T}\left(\rho + \frac{1}{T-1}\right)$, where ρ is the empirical autocorrelation coefficient of the transformed P-scores $v_t = \Phi^{-1}(u_t)$, where Φ is the standard normal distribution, and u_t is the one-step ahead predictive distribution of a value of the dependent variable in t given lagged observations up to $t-1$ and observations on other explanatory variables in t (see e.g. Frühwirth-Schnatter (1996)).

Table 5: Linear specification (with t-values) for the growth rates of loans to firms. The liquidity share is interacted with a dummy variable to account for the break in the level and the standard deviation of the series due to changing reporting definitions. The inference is based on the last 5,000 of the 7,000 iterations of the permutation sampler described in appendix A, whereby step (i) and (ii) are dropped, and step (iii) and (iv) are adjusted to a one-state specification. The AR(1) and AR(2) statistics denote the percentage of banks that have remaining autocorrelation in the residuals at the 5% significance level.

	interest rate	with size	with liquidity	with size and liquidity
dir_{t-1}	0.54*	0.54*	0.54*	0.76*
	(3.27)	(3.34)	(3.25)	(5.69)
dir_{t-2}	0.40*	0.40*	0.40*	
	(2.44)	(2.48)	(2.47)	
sum	0.94*	0.94*	0.93*	
	(6.28)	(6.38)	(6.39)	
$dir_{t-1} \cdot si_{t-1}$		0.08		0.09
		(0.68)		(0.38)
$dir_{t-2} \cdot si_{t-1}$		-0.16		
		(-1.36)		
sum		-0.08		
		(-0.70)		
$dir_{t-1} \cdot lish95_{t-1}$			-0.02	0.02
			(-1.07)	(0.34)
$dir_{t-2} \cdot lish95_{t-1}$			0.04*	
			(1.97)	
sum			0.02	
			(0.97)	
$dir_{t-1} \cdot lish96_{t-1}$			-0.05	0.06
			(-1.14)	(0.53)
$dir_{t-2} \cdot lish96_{t-1}$			0.14*	
			(3.53)	
sum			0.10	
			(1.92)	
$dir_{t-1} \cdot si_{t-1} \cdot lish95_{t-1}$				-0.00
				(-0.30)
$dir_{t-1} \cdot si_{t-1} \cdot lish96_{t-1}$				-0.01
				(-0.75)
log marginal likelihood	-53962.76	-53970.86	-53967.29	-53990.99
AR(1) significance at 5% level	0.08	0.08	0.08	0.08
AR(2) significance at 5% level	0.05	0.06	0.06	0.06

AR(1), AR(2): See note to table 4

of equation (1) for total loans and loans to firms, respectively. In each case, the best model (with lag order r and p) is determined by means of the marginal likelihood.[9] For all models estimated in the present paper, including five lags of the endogenous variable seems appropriate, i.e. $r = 5$ in all model specifications. The parameter estimates are obtained by using the last 5,000 of 7,000 iterations of the permutation sampler (adjusted to a one-state specification) described in appendix A. The effect of interest rate changes on bank lending remains quite robust across all model specifications. When including interaction terms, a 100 basis point increase in the short-term interest rate leads to a 0.5% increase in loans after 1 quarter. The effect is about half when no bank characteristics are included in the model for total loans, and is somewhat higher for loans to firms when both size and liquidity are included. Overall, the reaction of loans to firms is bigger than for total loans. There is nearly no evidence for cross-sectional asymmetry in banks' lending reaction as all coefficients on the interaction terms are insignificant for the total loans. In the model for loans to firms, however, the liquidity share seems to be the relevant characteristic driving a bank's lending reaction. The positive coefficient is significant in particular on the interaction term with liquidity from 1996 on. In terms of marginal log likelihood,[10] the preferred linear model for total loans is the one with the liquidity interaction. The equation moreover appears to be quite well specified as only 7% of the banks have remaining autocorrelation at the 5% significance level, and second order residual autocorrelation does not seem to be a problem. For loans to firms, 8% and 6% of the banks have remaining first- and second-order autocorrelation, respectively. Here, the preference for the specification including the interest rate only seems to be determined by the slightly better fit of the data.

The hypothesis that size may not be the bank characteristic determining cross-sectional asymmetries seems justified so far, as the interaction with size is not significant in the equation for both total loans and loans to firms. The positive effect of interest rate changes is somewhat puzzling, however. We might argue that the specific features of the Austrian banking sector described above help explain the apparently accommodating lending reaction to interest rate changes. Relatively small banks which concentrate their business on a local area dominate the Austrian banking system. Well-developed customer relationships thus reduce informational problems

[9] The marginal or "model" likelihood represents the likelihood of the data (y) under a certain model M, $L(y|M)$, and as such is independent of specific parameter values. Model specification tests can then be made by means of the Bayes factor. Estimating the marginal likelihood amounts to estimating the normalising constant of the posterior distribution of the model parameters θ: $\pi(\theta|y) = L(y|\theta)\pi(\theta)/L(y)$. In the present paper, all marginal likelihoods were estimated using the optimal bridge sampler (Meng and Wong, 1996, and Frühwirth-Schnatter, 2001b).

[10] The difference between two marginal log likelihoods is equal to the log of the Bayes factor, twice the difference is interpretable on the same scale as the familiar likelihood ratio statistic.

that tend to lead to adverse selection in loans allocation. When monetary policy tightens, banks thus are willing to expand their lending in order to cushion their customers from liquidity shortage. The argument is harder to apply when interest rates decrease, which was largely the case in Austria throughout the 1990s. Banks' lending cut might then simply be a passive adjustment due to decreased need for debt finance by the private sector during a period of relatively good economic performance. This would imply that the present estimation does not account for a demand component. However, two different issues might explain the positive coefficient. The first is documented in Frühwirth-Schnatter and Kaufmann (2001). Therein, nearly all banks of the balanced panel data set are used to estimate a loans' reaction model that allows for endogenous grouping of banks in the sense that banks are grouped according to their strength and their timely reaction to interest rate changes. Four groups emerge out of the data, with one group inclunding most of the banks. Only a few banks form the other groups; they are small in general, but some large banks with unusually high or low liquidity levels also fall into these groups. Size and liquidity do not seem to be defining elements of the various groups. However, allowing for a breakdown into four bank groups significantly refines the picture on bank lending. In the pooled model, we have a significant positive reaction in bank lending to interest rate changes, whereas in the model allowing for more than one group, the main group's reaction to interest rate changes is insignificant during periods of normal or above-average growth, and the reaction of the other smaller groups is negative. So the estimated positive interest rate effect in the present paper may also be due to the fact that banks might have a different timing in their lending reaction not accounted for in the pooled specification. The second issue may relate to a feature appearing in the correlations between the aggregates in section 2.2. Cutting the sample to the period of the economic recovery yields a negative correlation between lagged interest rate changes and the loan growth rates. There may be periods in which interest rate changes affect loans differently. Indeed, Frühwirth-Schnatter and Kaufmann (2001) find that the lending reaction is stronger during periods of below-average growth.

In the following, I will investigate this last issue further, not least because of the fact that accounting for the different timing in lending reaction between banks is not trivial in the present model set-up. First, I will assess whether the negative correlation between interest rates and aggregate loans is also reproducible in the dynamic panel specification. Then, the specification will be relaxed further to allow for a latent asymmetry over time in the sense that the periods in which interest rate changes affect lending differently are part of the model estimation. The reason for this is that we do not know a priori in which periods interest rate changes will have a stronger impact on lending and on cross-sectional asymmetry. The periods may evolve contemporaneously to the business cycle, or they may well lead it, instead. The latent state specification potentially accounts for this.

4 Introducing asymmetry over time

4.1 Model specification

To allow for changing effects of monetary policy over time, the model in (1) is extended in a straightforward manner to allow for state-dependent parameters:

$$\begin{aligned}\mathrm{dlo}_{it} = \beta_{1,0} + \sum_{q=1}^{3} \beta_{1,q} D_{qt} + \beta_{1,4}\mathrm{dp}_t + \beta_{1,5}\mathrm{dyr}_t + \beta_{1,6}\mathrm{si}_{it-1} + \beta_{1,7}\mathrm{lish95}_{it-1} + \\ \beta_{1,8}\mathrm{lish96}_{it-1} + (\beta_{1,9}\mathrm{lish95}_{it-1} + \beta_{1,10}\mathrm{lish96}_{it-1}) \cdot \mathrm{si}_{it-1} + \sum_{q=1}^{5} \beta_{1,10+q}\mathrm{dlo}_{it-q} + \\ \sum_{q=1}^{p} (\beta_{2S_t,1q}\mathrm{dir}_{t-q} + \beta_{2S_t,2q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1}) + \beta_{2S_t,3q}(\mathrm{dir}_{t-q} \cdot \mathrm{lish95}_{it-1}) + \\ \beta_{2S_t,4q}(\mathrm{dir}_{t-q} \cdot \mathrm{lish96}_{it-1}) + \beta_{2S_t,5q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1} \cdot \mathrm{lish95}_{it-1}) + \\ \beta_{2S_t,6q}(\mathrm{dir}_{t-q} \cdot \mathrm{si}_{it-1} \cdot \mathrm{lish96}_{it-1})) + \varepsilon_{it}, \quad (2)\end{aligned}$$

where again ε_{it} is i.i.d. $\mathcal{N}(0, \sigma^2)$. The meaning of the variables is the same as in (1). Now, however, the state-dependent parameters $\beta_{2S_t,\cdot}$ take on one out of 2 values, $\beta_{2S_t,\cdot} = \beta_{2j,\cdot}$ iff $S_t = j$, $j = 1, 2$.[11] S_t itself may be specified in different ways. As liquidity constraints may be more binding during periods of economic slowdown, we expect to observe a stronger reaction of bank lending to monetary policy during these times. A first possibility is to define S_t on an ad hoc basis by setting it to 1 during the period of recovery that prevails after the first quarter of 1993, and to 2 during the slowdown at the beginning of the observation period until the first quarter of 1993 (due to the lag specification, the effective estimation sample begins in the fourth quarter of 1991). However, as already mentioned, it may well be that periods of binding liquidity constraints are leading (or lagging) the economic cycle, or they may not even be related to the performance of the real economy at all. Therefore, we also investigate a latent specification for S_t, whereby the path of S_t is part of the model estimation. Within this second specification, S_t is assumed to follow a Markov process of order one with transition probabilities $\eta_{ij} = P(S_t = j | S_{t-1} = i)$, and $\sum_{j=1}^{2} \eta_{ij} = 1$. The Markov property is used here to reflect the fact that the two regimes may have a different duration.

[11] The investigation revealed only two states present in the data. Therefore, I present the model assuming two states only. The extension to more than two states is straightforward, however.

The next subsection investigates first the specification for S_t that defines it contemporaneously to the business cycle. The results proved to be quite robust across the extended linear model specifications of tables 4 and 5 including interaction terms with bank characteristics. Therefore, as the preferred linear model with interaction terms in terms of marginal likelihood (see bottom panel of tables 4 and 5) is the one that includes the interaction between the interest rate and the liquidity share, results on this specification are reported. In addition, results including only the interest rate changes are discussed because they proved to be interestingly different from the more sophisticated specifications. Subsequently, the results of all models with the latent state specification are displayed, and the preferred model specification is discussed in more detail.

4.2 Ad hoc specification of S_t

To get a first impression on whether effects of monetary policy are asymmetric over time, we assume S_t to follow the business cycle contemporaneously. According to figure 1, $S_t = 1$ in the period of the recovery identified to have begun in the second quarter of 1993, and $S_t = 2$ during the economic slowdown at the beginning of the observation period through the first quarter of 1993. Due to lag specifications, the effective estimation sample begins right away with $S_t = 2$ in the fourth quarter of 1991.

Table 6 reports the results for the total loans' estimates and the ones for loans to firms. Note here that as $S_t = 1$ during the whole period from 1996 onwards, we can only estimate the effect of liquidity from 1996 onwards for state 1. For total loans, there is no strong evidence for state-dependent interest rate effects in the specification including the interaction with liquidity (and also in the specifications not reported here including size, and size and liquidity simultaneously). In both states, we have a significant positive effect of lagged interest rate changes on total loans. As in the linear model, there is hardly any evidence for cross-sectional asymmetry, either. The most parsimonious model including only interest rate changes presents an interesting picture, however. The positive effect of lagged interest rate changes is significant while state 2 prevails. In state 1, interest rate changes do not have a significant effect, however. The second hypothesis that was based on the specificities of the Austrian banking sector seems to get justified in this setting. Due to tight relationships, banks are willing to shield their customers from monetary policy effects. Overall, the effect is smaller during state 1 than during state 2.

With respect to the direct overall effect of interest rate changes, the results for loans to firms stand in contrast to the ones for total loans. Still, lagged interest rate changes

Table 6: Evidence on asymmetry over time. $S_t = 1$ during the period of recovery after 1993:Q1, $S_t = 2$ during the recession period until 1993:Q1. The liquidity share is interacted with a dummy variable to account for the break in the level and the standard deviation due to changing reporting definitions. The interaction of the interest rate with the liquidity share from 1996 onwards is estimated only for state 1. The inference is based on the last 5,000 of the 7,000 iterations of the sampler described in appendix A. Step (i) and (ii) are dropped, step (iii) holds S_t fixed.

	Total loans				Loans to firms			
	interest rate		with liquidity		interest rate		with liquidity	
state	1	2	1	2	1	2	1	2
dir_{t-1}	-0.04	0.64*	0.50*	0.46*	0.43*	0.63*	0.42*	0.64*
	(-0.26)	(3.69)	(4.47)	(3.41)	(2.10)	(2.55)	(2.00)	(2.64)
dir_{t-2}	0.08	-0.34			0.72*	-0.26	0.71*	-0.27
	(0.51)	(-1.62)			(3.50)	(-0.89)	(3.51)	(-0.93)
dir_{t-3}	0.58*	0.95*						
	(3.98)	(2.29)						
sum	0.62*	1.26*			1.15*	0.37	1.13*	0.37
	(4.80)	(2.88)			(6.41)	(1.47)	(6.42)	(1.53)
$\text{dir}_{t-1} \cdot \text{lish95}_{t-1}$			0.01	-0.01			-0.01	-0.03
			(1.18)	(-0.86)			(-0.40)	(-1.15)
$\text{dir}_{t-2} \cdot \text{lish95}_{t-1}$							0.02	0.05*
							(0.86)	(1.99)
sum							0.01	0.03
							(0.58)	(1.14)
$\text{dir}_{t-1} \cdot \text{lish96}_{t-1}$			-0.00				-0.05	
			(-0.86)				(-1.14)	
$\text{dir}_{t-2} \cdot \text{lish96}_{t-1}$							0.14*	
							(3.47)	
sum							0.10	
							(1.94)	
log marg. lik.	-48770.69		-48758.85		-53956.40		-53963.76	
AR(1) significance at 5% level	0.08		0.08		0.09		0.08	
AR(2) significance at 5% level	0.04		0.04		0.06		0.04	

AR(1), AR(2): See note to table 4

have a positive effect on lending, and the difference between the states does not seem to be very significant. Taking into account the offsetting effect in state 2, however, leads to an insignificant effect of interest rate changes for loans to firms, whereas the positive effect is reinforced in state 1. This leads to a stronger effect of interest rate changes during the period of economic recovery than during the slowdown at the beginning of the observation period. Again, the bank characteristic dtermining cross-sectional asymmetric bank lending behaviour is liquidity, the liquidity effect being significantly positive up to and from 1996 onwards. Worth mentioning is finally that all model specifications are preferred to the linear one in terms of marginal likelihood, twice the difference between the state-dependent and the linear model ranging from 7 (for loans to firms with the liquidity interaction) to 15 (for total loans with the interest rate only).
To summarize, despite the evidence for state-dependent parameters not being that obvious at first sight, there is clearly some scope for time asymmetry. The different state relevance for total loans and loans to firms implies that lending to households may be less accommodative than lending to firms during the period of economic recovery. This issue will be assessed in a follow-up investigation.

4.3 Latent specification of S_t

Within the latent switching specification, S_t itself is interpreted as an unobserved random variable, and as such is part of the estimation procedure along with the transition probabilities. The inference is obtained by iterating over the permutation sampler described in appendix A for 7,000 times. The last 5,000 are retained to compile table 7 that provides mean estimates of the parameters of interest (appendix B describes how the state-specific parameters were identified). The results are now robust through all model specifications, and qualitatively equal between overall lending and lending to firms. In general, we can discriminate between two different states, whereby stronger, significantly positive effects of interest rate changes are recorded during state 2, whereas interest rate changes affect lending insignificantly while state 1 is prevailing. A transitory negative effect of interest rate changes in state 2 is obtained in the specification which includes the interaction of the interest rate with size in the total loans equation. A 100 basis points increase in the interest rate leads to a contraction of bank lending of more than 3%. The overall effect in this specification remains positive (+0.9%), however, as in the first period banks react in an accommodative way to interest rate increases. Cross-sectional asymmetry is not significant in state 1, while in state 2 there is a positive liquidity effect in both total lending and lending to firms. The liquidity effect in the total loans equation does not seem to be

Table 7: Total loans: Evidence on the bank lending channel(with t-values). Latent Markov switching specification of the state variable. The liquidity share is interacted with a dummy variable to account for the break in the level and the standard deviation due to changing reporting definitions. The inference is based on the last 5,000 of the 7,000 iterations of the sampler described in appendix A. The state-specific parameters are identified according to the procedure described in appendix B.

	interest rate		with size		with liquidity		with size and liquidity	
state	1	2	1	2	1	2	1	2
dir_{t-1}	-0.03	4.39*	0.01	4.13*	0.18	4.67*	0.18	4.59*
	(-0.49)	(7.07)	(0.08)	(9.50)	(1.73)	(7.66)	(1.74)	(6.86)
dir_{t-2}	0.01	0.55	0.43*	-3.23*				
	(0.10)	(0.98)	(2.94)	(-7.84)				
dir_{t-3}	0.38*	2.33*						
	(3.09)	(3.80)						
sum	0.33*	7.27*	0.44*	0.91*				
	(2.46)	(6.58)	(2.88)	(5.62)				
$\text{dir}_{t-1} \cdot \text{si}_{t-1}$			-0.02	-0.38			-0.01	-0.46
			(-0.19)	(-1.13)			(-0.08)	(-0.55)
$\text{dir}_{t-2} \cdot \text{si}_{t-1}$			-0.14	0.57				
			(-1.55)	(1.76)				
sum			-0.16	0.19				
			(-1.52)	(1.73)				
$\text{dir}_{t-1} \cdot \text{lish95}_{t-1}$					-0.02	0.21*	-0.04	0.22
					(-1.83)	(3.73)	(-0.97)	(1.12)
$\text{dir}_{t-1} \cdot \text{lish96}_{t-1}$					-0.01	0.01	-0.03	-0.15
					(-0.22)	(0.01)	(-0.44)	(-0.08)
$\text{dir}_{t-1} \cdot \text{si}_{t-1} \cdot \text{lish95}_{t-1}$							0.00	-0.00
							(0.53)	(-0.16)
$\text{dir}_{t-1} \cdot \text{si}_{t-1} \cdot \text{lish96}_{t-1}$							0.01	0.05
							(0.45)	(0.02)
η_{11}	0.95		0.82		0.95		0.94	
	(0.81 1.00)		(0.58 0.97))		(0.82 1.00)		(0.77 1.00)	
η_{22}	0.66		0.50		0.69		0.69	
	(0.28 0.95)		(0.19 0.83)		(0.31 0.95)		(0.31 0.96)	
log marg. lik.	-48763.33		-48776.36		-48750.21		-48774.75	
AR(1) significance at 5% level	0.08		0.08		0.07		0.07	
AR(2) significance at 5% level	0.04		0.04		0.04		0.04	

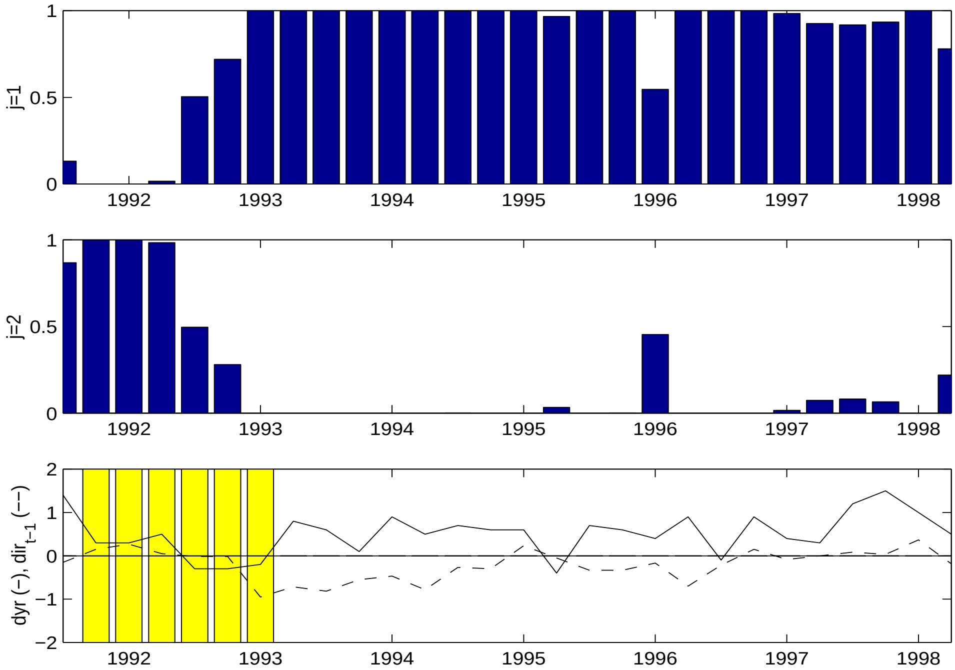
AR(1), AR(2): See note to table 4

Table 8: Loans to firms: Evidence on the bank lending channel(with t-values). Latent Markov switching specification of the state variable. The liquidity share is interacted with a dummy variable to account for the break in the level and the standard deviation due to changing reporting definitions. The inference is based on the last 5,000 of the 7,000 iterations of the sampler described in appendix A. The state-specific parameters are identified according to the procedure described in appendix B.

	interest rate		with size		with liquidity		with size and liquidity	
state	1	2	1	2	1	2	1	2
dir_{t-1}	-0.35	5.08*	-0.37	5.19*	0.16	5.54*	0.24	5.48*
	(-1.80)	(8.42)	(-1.92)	(9.38)	(1.04)	(10.73)	(1.67)	(10.78)
dir_{t-2}	0.21	1.15	0.24	1.17*				
	(0.97)	(1.67)	(1.16)	(1.95)				
dir_{t-3}	0.66*	1.21	0.66*	1.30				
	(3.35)	(1.43)	(3.52)	(1.52)				
sum	0.52*	7.44*	0.53*	7.66*				
	(2.84)	(6.56)	(2.93)	(6.83)				
$dir_{t-1} \cdot si_{t-1}$			0.11	-0.63			0.15	-0.99
			(0.84)	(-1.39)			(0.60)	(-1.28)
$dir_{t-2} \cdot si_{t-1}$			0.02	-1.07*				
			(0.17)	(-2.63)				
$dir_{t-3} \cdot si_{t-1}$			-0.10	0.22				
			(-0.73)	(0.29)				
sum			0.03	-1.48				
			(0.21)	(-1.74)				
$dir_{t-1} \cdot lish95_{t-1}$					-0.02	0.17*	-0.03	0.24
					(-1.13)	(3.21)	(-0.47)	(1.25)
$dir_{t-1} \cdot lish96_{t-1}$					-0.03	0.41	0.13	-2.31*
					(-0.68)	(1.76)	(1.18)	(-4.45)
$dir_{t-1} \cdot si_{t-1} \cdot lish95_{t-1}$							0.00	-0.02
							(0.27)	(-0.62)
$dir_{t-1} \cdot si_{t-1} \cdot lish96_{t-1}$							-0.02	0.31*
							(-1.36)	(4.09)
η_{11}	0.85		0.86		0.87		0.84	
	(0.65 0.97)		(0.68 0.97))		(0.67 0.98)		(0.64 0.96)	
η_{22}	0.60		0.61		0.63		0.58	
	(0.25 0.89)		(0.25 0.89)		(0.32 0.90)		(0.25 0.88)	
log marg. lik.	-53935.06		-53940.81		-53940.42		-53959.47	
AR(1) significance at 5% level	0.08		0.08		0.07		0.07	
AR(2) significance at 5% level	0.05		0.06		0.05		0.05	

AR(1), AR(2): See note to table 4

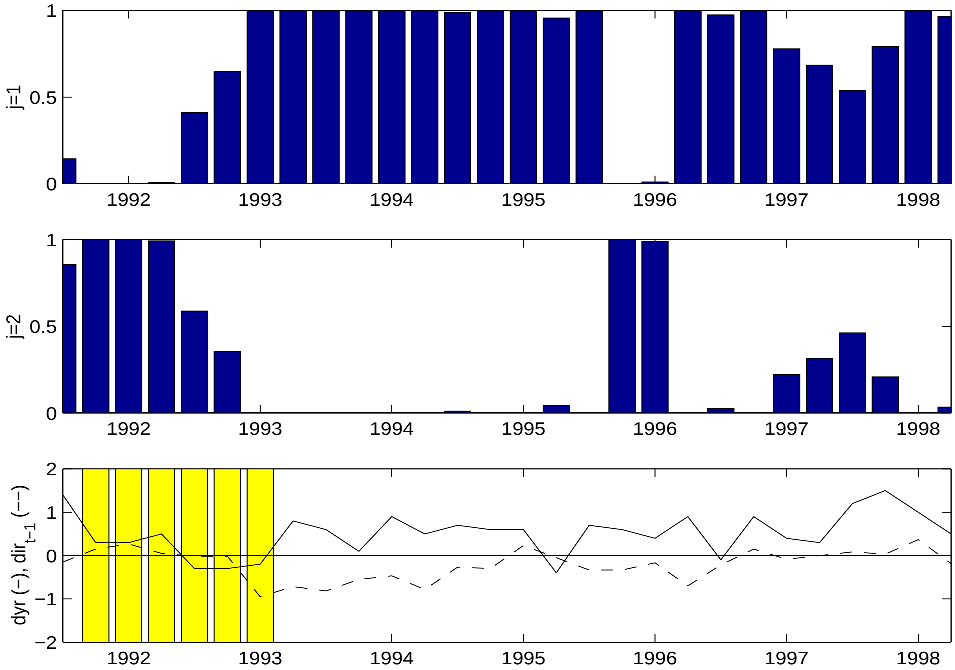
Figure 2: Total loans: Posterior state probabilities, obtained by averaging over all paths of S_t, each one simulated in step (i) at each iteration over the sampler described in appendix A. Bottom panel: GDP growth rate (dyr) and lagged interest rate changes ($\text{dir}_t - 1$), the shaded area refers to the economic slowdown of 1992/1993.



state-dependent from 1996 onwards, however. The estimation was refined to restrict the liquidity effect from 1996 onwards to be state-independent. The results are not documented here, as the coefficients proved to be nearly unchanged when compared to the ones documented in the table.

Note, moreover, that a common feature to all specifications is the higher persistence of the first state relative to the second one (see estimates of η_{11} and η_{22} at the bottom of the table). Clearly, the marginal likelihood favors the latent switching specification in any case to the linear and the extended linear specification with fixed S_t, twice the difference between the log marginal likelihood of the linear and the latent specification being above 40 in each case. To get an idea of what the estimated state variable tracks, the posterior state probabilities are depicted in figures 2 and 3 for the total loans and the loans to firms equation, respectively. In both, the state variable neatly relates to the business cycle. State 2 identifies the turning point in the third quarter of 1991 and tracks the slowdown in the first half of 1992. For loans to firms, the sampler additionally identifies state 2 prevailing for another six months, in particular the last quarter of 1995 and first quarter of 1996 during the observation period. This half year coincides with the quarters that recorded the strongest loan growth during the recovery.

Figure 3: Loans to firms: Posterior state probabilities, obtained by averaging over all paths of S_t, each one simulated in step (i) at each iteration over the sampler described in appendix A. Bottom panel: GDP growth rate (dyr) and lagged interest rate changes ($\text{dir}_t - 1$), the shaded area refers to the economic slowdown of 1992/1993.



In general, when state 2 prevails, the positive liquidity effect yields a stronger accommodative lending reaction to interest rate changes for liquid banks (see table 9)[12], while interest rate changes are nearly insignificant when state 1 prevails. The exception represents lending to firms by liquid banks which is significant from 1996 onwards in state 1. Note however, that the macroeconomic relevance is minor, as these banks account only for about 1% of the credit market (see table 2).

[12]A liquid (illiquid) bank is a bank of median liquidity within the upper 5th (the lower 50th) percentile of liquidity shares in the respective subperiod. For instance, the total effect of monetary policy for a liquid bank in state 1 up to 1995 is computed as:

$$\gamma^{95}_{1,\text{liq}} = \beta_{21,11} + \beta_{21,21} \cdot \overline{\text{lish95}}_{\text{liq}},$$

where $\overline{\text{lish95}}_{\text{liq}}$ is the median liquidity share of the relative 5% most liquid banks up to 1995.

Table 9: Mean total effect (with t-value) of monetary policy on the lending reaction of a bank of median liquidity within the class of the relative 5% most (liquid), and the relative 50% least liquid banks (illiquid).

	sum dir	sum liquid		sum illiquid	
		up to 95	from 96 on	up to 95	from 96 on
			Total loans		
state 1	0.19	-0.35	0.12	0.33	0.22
	(1.86)	(-1.11)	(0.30)	(2.63)	(1.36)
state 2	4.40	9.74	4.32	3.07	4.42
	(7.02)	(6.36)	(5.83)	(4.35)	(6.94)
			Loans to firms		
state 1	0.16	-0.29	0.68	0.27	-0.01
	(1.04)	(-0.68)	(2.88)	(1.49)	(-0.05)
state 2	5.54	9.77	6.07	4.47	5.37
	(10.73)	(6.86)	(11.00)	(7.35)	(10.36)

5 Conclusion

The present paper investigates the cross-sectional and the time dimensions of the asymmetry in bank lending reaction to interest rate changes. A panel of quarterly individual bank balance sheet data is used that covers the period from the second quarter of 1990 through the second quarter of 1998. The data actually used in the analysis cover around 50% of the Austrian banking sector. However, despite this quite strict cleaning procedure, the remaining data reproduce the distribution of the original sample quite well, and contain reliable information on the lending behaviour of Austrian banks.

An initial look at the data reproduces the main characteristics of the Austrian banking sector. The banking sector is generally dominated by small banks that are embedded in a multi-tier system and do most of their business locally. Most inter-regional and international activities are handled through their central institutions, which themselves are among of the largest Austrian banks. Moreover, a system of mutual financial assistance, underpinned in many cases by a public guarantee, characterises the savings' and the credit cooperatives' sector.

The first evidence on monetary policy effects on bank lending reaction provides apparently an "interest rate puzzle". Within a linear specification including the interest rate change (to measure monetary policy), and interaction terms with alternatively, and both simultaneously, size and liquidity, a positive effect of monetary policy changes emerges, documenting an accommodative lending behaviour of banks. While there is no indication for differential effects on total loans that may be related to bank features, there is evidence for a liquidity effect in the lending reaction to firms.

One of the reasons that may account for this positive interest rate effect is some potential time asymmetry in banks' lending reaction. A simple correlation analysis at the aggregate level reveals that the loan growth rate is negatively correlated to interest rate changes in particular during the recovery period identified to have lasted from the second quarter of 1993 through the end of the sample. The analysis assesses whether this negative correlation can be reproduced at the micro-level by allowing for state-dependent parameters. State 1 parameters represent accordingly the effect of interest rate changes during the period of the economic recovery, state 2 parameters the respective effect during the period of the economic slowdown at the beginning of the sample. The evidence for state-dependent parameters and for cross-sectional asymmetry is still rather weak in this setting for total loans. Interestingly, lending to firms reacts overall insignificantly during the period of the economic slowdown, while, still, during the economic recovery period interest rate changes have a positive effect on corporate loans. Again, liquidity appears to be the characteristic determining cross-sectional asymmetry. In terms of marginal likelihood, the state-dependent specification clearly performs better than the linear one.

The full latent switching state specification reveals clearly an asymmetric effect of monetary policy over time. In the total loans equation, the posterior probabilities of state 2 track the first half of the economic slowdown in 1992, and also identify the turning point in the third quarter of 1991 to pertain to state 2. When state 1 prevails, bank lending does not react significantly to lagged interest rate changes, and evidence on cross-sectional asymmetry is again rather insignificant. The interest rate effect is still positive in state 2, and a significant liquidity effect is reported during state 2 for total loans and corporate loans.

In particular, the inferred insignificant effect of lagged interest rate changes on lending in state 1 is interpretable if one takes into consideration the specificities of the Austrian banking sector. Most banks are small and operate on a local level; therefore they tend to be less exposed to informational asymmetry. Furthermore, the multi-tier system in which they are embedded alleviates the tightness of liquidity constraints especially after restrictive monetary policy actions. Moreover, due to close relationships, banks are willing to shield their customers in periods of tight liquidity. Size may thus not be the adequate bank characteristic determining cross-sectional asymmetries in bank lending reaction after all, and restrictive lending may not be observed after interest rate changes. These hypotheses are confirmed in the state-dependent specification.

Finally, note that more differentiated results are obtained in Frühwirth-Schnatter and Kaufmann (2001), where the same data set was used to infer on the bank lending channel by specifying a model where the grouping of banks that differ in the strength of their lending reaction to interest rate changes is part of the estimation procedure. The result is that size and liquidity are not among the defining elements of the various bank groups. For most banks, however, those results document a transitory negative effect of interest rate changes on bank lending during quarters broadly related to below-average growth rates, while the effects are nearly insignificant during quarters of above-average growth.

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A Sampling scheme

To simplify notation in the following, we rewrite the model introduced in (2) in a compact way:

$$\begin{aligned} y_t &= X_{1t}\beta_1 + X_{2t}\beta_{2S_t} + \varepsilon_t, \\ \varepsilon_t &\sim \mathcal{N}(0, \sigma^2 I_N), \end{aligned} \tag{3}$$

where y_t is a $N \times 1$ vector gathering all bank observations of period t, and I_N denotes the identity matrix of dimension N. X_{1t} and X_{2t} are designed accordingly, gathering the observations on the variables that are assumed to have a state independent, and a state dependent effect on bank lending, respectively. Thus, the constant, the seasonal dummies, the control variables and lagged values of y_t enter X_{1t}, and the lagged values of the first difference of the interest rate, its interaction with size and liquidity are in X_{2t}.

The Bayesian approach pursued in the present paper circumvents some problems usually encountered when the inference is based on standard maximum likelihood methods. In particular, the numerical maximization of the likelihood proves to be highly sensitive with respect to starting values. Often, it is subject to boundary problems that may cause the estimation to break down (e.g. when some transition probabilities turn zero). For estimation, the path of S_t, $S^T = (S_1, \dots, S_T)$, is interpreted as an additional random variable, on which we have to draw an inference. The vector of all model parameters, $\theta = (\beta_1, \beta_{21}, \beta_{22}, \eta, \sigma^2)$, where $\eta = (\eta_{1\cdot}, \eta_{2\cdot})$, with $\eta_{j\cdot} = (\eta_{j1}, \eta_{j2})$, $j = 1, 2$, collects the transition probabilities, is therefore augmented to yield the *augmented* parameter vector $\psi = (\theta, S^T)$. The estimation procedure yields an inference on the posterior distribution of ψ. As its derivation is analytically not feasible, Markov chain Monte Carlo simulation methods are applied to obtain a sample out of the posterior distribution of ψ by iteratively simulating out of the *conditional* posterior distributions of θ and S^T.

The following assumptions characterise the prior distributions of the parameters:

- The parameters are independent *a priori*, $\pi(\theta) = \pi(\eta)\pi(\beta_1, \beta_{21}, \beta_{22})\pi(\sigma^2)$.
- $\eta_{1\cdot}, \eta_{2\cdot}$ are independent *a priori* and follow a Dirichlet distribution, $\eta_{i\cdot} \sim D(e_{i1}, e_{i2})$, $i = 1, 2$.
- $\beta = (\beta_1, \beta_{21}, \beta_{22})$ is assumed to have a normal prior, $\mathcal{N}(b_0, B_0^{-1})$.
- The prior distribution of σ^2 is inverse Gamma, $IG(g_0, G_0)$.

For practical implementation, the hyperparameters were set in a way to be rather uninformative, i.e. $e_{11} = e_{22} = 2$, $e_{12} = e_{21} = 1$, $b_0 = (0, \dots, 0)$, $B_0 = \frac{1}{4} \cdot I$, $g_0 = G_0 = 1$, where I denotes an appropriately dimensioned identity matrix.

The posterior inference on the model in (3) is obtained by iterating over the following steps:

(i) $\pi(S^T | y, \beta, \sigma^2, \eta)$

(ii) $\pi(\eta | S^T)$

(iii) $\pi(\beta | y, S^T, \sigma^2)$

(iv) $\pi(\sigma^2 | y, S^T, \beta_1, \beta_2)$.

Step (i) is by now standard in Bayesian analysis. It involves a forward filtering and a backward sampling step, where S^T is simulated out of its conditional posterior distribution as derived e.g. in Carter and Kohn (1994), Shephard (1994), and more explicitly for Markov switching models in Chib (1996).

Given the actual simulated path S^T, step (ii) is readily available. The posterior distribution of η is a product of 2 independent Dirichlet distributions,

$$\pi(\eta|S^T) = \prod_{i=1}^{2} \pi(\eta_{i\cdot}|S^T) = \prod_{i=1}^{2} D(e_{i1} + M_{i1}, e_{i2} + M_{i2}),$$

where $M_{ij} = \#\{S_t = j|S_{t-1} = i\}$.

To derive the posterior distribution in step (iii), we create the auxiliary dummy variables S_t^j, $j = 1, 2$, where $S_t^j = 1$ iff $S_t = j$, and 0 otherwise. Equation (3) is then expressed as:

$$\begin{aligned} y_t &= X_{1t}\beta_1 + X_{2t}\beta_{2S_t} + \varepsilon_t \\ &= X_{1t}\beta_1 + X_{2t}S_t^1\beta_{21} + X_{2t}S_t^2\beta_{22} + \varepsilon_t. \end{aligned} \tag{5}$$

Obviously, the conditional posterior distribution of $\beta = (\beta_1, \beta_{21}, \beta_{22})$ is normal $\mathcal{N}(b, B)$, where $B = (\sigma^{-2}X'X + B_0)^{-1}$ and $b = B(\sigma^{-2}X'y + B_0b_0)$. X is the predictor matrix of equation (5),

$$X = \begin{bmatrix} X_{11} & S_1^1X_{21} & S_1^2X_{21} \\ \vdots & & \\ X_{1T} & S_T^1X_{2T} & S_T^2X_{2T} \end{bmatrix},$$

and y gathers all left-hand variables.

Given actual simulated values of all parameters and S^T, the conditional posterior distribution of σ^2 is inverse Gamma $IG(g, G)$, with $g = g_0 + \frac{1}{2}NT$ and $G = G_0 + (y - X\beta)'(y - X\beta)$.

B State-dependent parameter identification

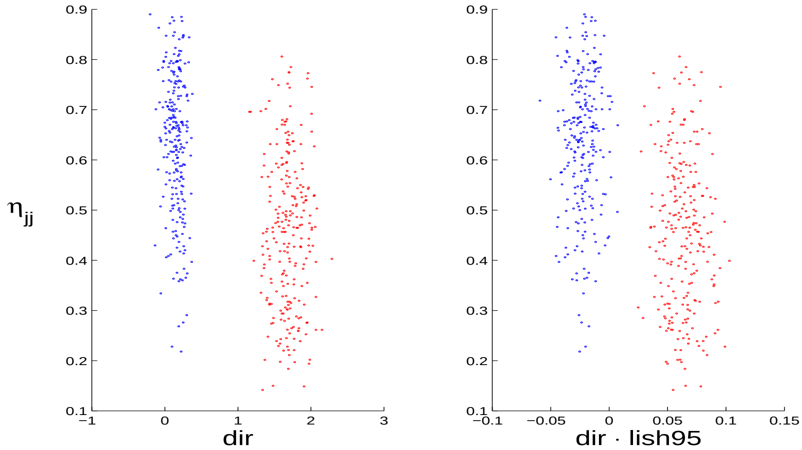
The presence of 2 states is reflected in significantly different state-specific parameters. Note that the simulated parameter values are not restricted while iterating over the sampling steps described in the previous appendix. State identification (i.e. identifying the parameter that uniquely defines the states) is performed subsequently by post-processing the simulated parameter values in an explorative manner. The identification step is illustrated here by using the simulated state-specific coefficients of the specification including the switching interaction between the interest rate difference and the liquidity share up to 1995 only. Figure 4 depicts scatter plots of the simulated values for these coefficients against persistence η_{jj}, respectively. The plots indeed confirm the presence of two distinct states. Their identification is possible by means of either coefficient. The results presented in the paper are obtained using the restriction:

$$\beta_{21,11} < \beta_{22,11},$$

i.e. if the simulated values for $\beta_{21,11}$ and $\beta_{22,11}$ happen to violate the restriction, the vectors of the state-specific parameters and the simulated values of the state variable are permuted in order to fulfill the restriction:

$$
\begin{aligned}
(\beta_{21}, \beta_{22}) &:= (\beta_{22}, \beta_{21}) \\
\eta &:= (\tilde{\eta}_1, \tilde{\eta}_2), \quad \begin{array}{l} \tilde{\eta}_1 = (\eta_{22}, \eta_{21}) \\ \tilde{\eta}_2 = (\eta_{12}, \eta_{11}) \end{array} \\
S^T &:= 3 - S^T
\end{aligned}
$$

Figure 4: Scatter plot of simulated values for the coefficient on the interest rate (dir) and its interaction with liquidity (dir·lish95) against persistence η_{jj}, respectively.



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