Banking crises and nonlinear linkages between credit and output

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The paper employs a recently developed procedure, based on a bivariate Markov switching model, to analyze the asymmetric causality linkages between credit growth and output growth during banking crises. Using a sample of 103 banking crises, we find that neither credit nor output leads the other variable in calm and crisis periods, although there is evidence of instantaneous regime-interdependence between the banking and real sector during crises. The linear link between credit growth and output growth is also regime-dependent.

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1. Introduction

Several theoretical studies argue that credit acts as a nonlinear propagator of shocks to the economy. Fluctuations in credit can even be the "cause" of business cycles (e.g. Blinder and Stiglitz 1983, Blinder 1987, Bernanke and Gertler 1989, Kiyotaki and Moore 1997, Azariadis and Smith 1998, Cordoba and Ripoll 2004). For example, Blinder (1987) constructs a model of credit rationing in which monetary shocks have stronger effects when the economy is in a credit-rationing regime. Bernanke and Gertler (1989) develop a model of the business cycle in which borrowers' balance sheet conditions are a source of investment and output fluctuations.

More recently, Azariadis and Smith (1998) construct a dynamic equilibrium model explaining the relationship between credit and production, where the system can switch between the Walrasian and credit rationing regimes. In one version of this model, the economy experiences stochastic shifts between regimes in a Markovian manner, with the probability of regime transitions depending on the state of the system. The regime transitions are associated with fluctuations in output and capital stock. Cyclical contractions also involve declines in real interest rates, increases in credit rationing and withdrawal of savings from banks.

The study of Azariadis and Smith provides a theoretical rationale for empirical analyses of nonlinear, regime-dependent relationships between credit rationing and economic activity (McCallum 1991, Galbraith 1996, Balke 2000, Calza and Sousa 2006, Kaufmann and Valderrama 2007). McCallum (1991) estimates the effect of monetary growth on output, using the standard regression model with dummy variables, and finds that the effect is stronger when an indicator of credit rationing exceeds a certain threshold. Similarly, Galbraith (1996), Balke (2000), Calza and Sousa (2006) estimate threshold regime-switching models and conclude that monetary and credit shocks have larger effects on economic activity in a credit-rationing regime. Psaradakis, Ravn and Sola (2005) and Kaufmann and Valderrama (2007) employ Markov-switching models and also find asymmetric money-output and credit-output linkages, respectively.

Nonlinear dependencies between credit and output take on special importance during banking crises. Banking crises are extreme examples of shocks to the credit market that should not only be capable of transferring the banking sector into the credit-rationing regime, but also significantly affect the economic activity. Thus, it is highly probable that banking crises impact the link between credit and output.

In the related literature on banking crises, disagreements persist on the casual direction of credit market conditions on economic growth. The falling output growth is considered as a good predictor of banking crises (Kaminsky and Reinhart 1999, Demirgüç-Kunt and Detragiache 2005), which suggests that recessions may lead to banking crises and lower credit growth. There also exist effects in the opposite direction, because banking crises are usually accompanied by significant reductions in output growth (e.g. Demirgüç-Kunt and Detragiache 1998; Boyd, Kwak and Smith 2005; Hutchison and Noy 2005; Demirgüç-Kunt, Detragiache and Gupta 2006; Ranciere, Tornell and Westermann 2007).

Our paper extends earlier empirical research by considering a new methodology to test for nonlinear linkages between credit and output during banking crises. We construct a regime-switching model that allows both credit and output to enter one of the regimes of calm and crises. Such a model fits well the theoretical arguments of changing relationships between credit and output during business and credit cycles. It also facilitates analysing linear and nonlinear dependencies between the banking sector performance and economic activity, because all bilateral linkages are allowed to change in different regimes of the economy.

In contrast to earlier theoretical and empirical research, the proposed model allows the variables, credit and output growth, to change their regimes independently or at least in different periods. For example, the banking sector can follow or precede the real sector in entering the specific regimes of calm or crisis.

This feature of our model enables us to test for asymmetric Granger causality and regime-dependence between credit and output, using the method recently proposed in Białkowski, Bohl and Serwa (2006). To our best knowledge, this is the first application of this novel methodology to the analyses of the link between credit and output. We further extend the set of possible hypotheses from Białkowski et al. by allowing for mixtures of asymmetric no-causality and no-dependence relationships, determined by the states of credit and real sectors.

The applied tests provide important information on the sequence of entering the specific regimes by credit and output. If the processes of regime-switching for credit and output are independent, it suggests that banking crises have a limited impact on business cycles. Conversely, the regime-dependence implies lagged or instantaneous bidirectional causality between credit and output. In the presence of instantaneous causality the banking and real sectors most likely enter the crises simultaneously. If credit leads output into turmoil, then the crises affect real cycles and induce economic costs with a possible delay. If output precedes credit into the crisis regime, it means that recessions increase the probability of banking crises in the next period.

Our results indicate that both credit growth and output growth slow down significantly and become more volatile in turbulent periods. We find no significant evidence of causality effects from output to the credit market or in the opposite direction in any regime, but the credit sector and the real economy frequently enter the same regimes simultaneously. The model shows that the linear link between the analysed variables is also regime-dependent. The velocity of falling credit is also a good measure of the size of a banking crisis, which enables us to measure how the size of a crisis is related to the fall in output growth.

The rest of the paper is organized as follows: Section 2 presents our regime-switching model explaining the behaviour of credit and output. The tests of causality and regime-independence are also described. Section 3 discusses data and results from our testing framework and presents the final model. Section 4 concludes.

2. Modelling the relationship between credit and output

In this section we present our model of credit growth and output growth, and explain the methodology to test for nonlinear linkages between these variables.

Azariadis and Smith (1998) construct a theoretical model, where the credit market and the real economy enter prosperity and slow-down regimes simultaneously. We extend their approach in our empirical analysis by considering the separate regime-switching processes of credit and output. Similar statistical models to the one employed in our analysis were used to estimate relationships between financial markets during crises, linkages between growth rates in different countries during business cycles, and dependencies between output growth and prices and stock returns (Phillips 1991, Ravn and Sola 1995, Edwards, Susmel 2001, Sola, Spagnolo and Spagnolo 2002).

Furthermore, we employ the methodology for testing asymmetric causality in a Markov switching framework, which was recently proposed by Białkowski, Bohl, and Serwa (2006). We also construct the additional tests that allow for switching between different types of credit-output dependencies over time.

2.1. The model of credit growth and output growth

Let Z be the vector $[X,Y]'$, where $X = \{x_{nt}; n,t \in N\}$ and $Y = \{y_{nt}; n,t \in N\}$ are the two cross-sectional time series. The variables *X* and *Y* can be interpreted as real credit growth and real output growth, respectively (the opposite setting, where X is an output growth and Y is a credit growth, is also used). Symbol n denotes the market on which a banking crisis occurs and t is the time index.

Both variables are allowed to enter one of the two complementary states of "crisis" and "calm" periods.[1] Using all four combinations of these states we construct a Markov process with four regimes and we use the index s to denote these regimes. "X and Y are in the calm states" defines the first regime $(s=1)$. "X is in the calm state and Y is in the crisis state" denotes the second one $(s=2)$. The third regime indicates that "X is in the crisis state and Y is in the calm state" $(s=3)$. "X and Y are in the crisis states" defines the fourth regime $(s=4)$. At each point in time, the state s is determined by an unobservable Markov chain. The dynamics of the Markov chain are described by a 4×4 transition matrix P:

$$P=\begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{pmatrix}, \qquad (1)$$

where p_{ij} denotes the probability of changing the state from i to j.

Credit growth and output growth are conditionally normally distributed with means and variances dependent on the regimes of calm and crisis. We expect low means and high volatilities when both financial and real sectors are in the crisis state, and high means and low variances when both sectors are in the tranquil state.

Lower mean of real credit growth during a banking crisis is usually due to bank failures, preventive policies of troubled banks, restrictive credit limits, lack of confidence in banks and lower deposit growth. Lower output growth is related to increased government spending and less borrowing during a crisis, which causes less investment, consumption and trade.

Empirical studies show that low output growth is usually associated with increased output growth volatility, for example during financial crises (e.g. Ramey and Ramey 1995). Similarly, the variability of credit growth often changes during a crisis. Sudden drops in credit growth, caused by financial problems of banks, and rapid adjustments of credit markets to news may be responsible for the increased volatility. High variance of credit growth during crises also reflects different types of banking crises, where sizeable contractions in credit may

[1] We use expressions “states” and “regimes” interchangeably to discriminate between periods of calm and crisis.

happen after the burst of the lending bubble or less significant and more gradual credit tightening is possible during the long-lasting increase of non-performing loans.

The parameter space for means, variances and covariances between credit and output variables is defined as follows:

$$\mu = \left\{ \mu_{s=1} = \begin{bmatrix} \mu_T^X \\ \mu_T^Y \end{bmatrix}, \mu_{s=2} = \begin{bmatrix} \mu_T^X \\ \mu_C^Y \end{bmatrix}, \mu_{s=3} = \begin{bmatrix} \mu_C^X \\ \mu_T^Y \end{bmatrix}, \mu_{s=4} = \begin{bmatrix} \mu_C^X \\ \mu_C^Y \end{bmatrix} \right\}, \quad (2)$$

$$\sigma = \left\{ \sigma_{s=1} = \begin{bmatrix} \sigma_T^X \\ \sigma_T^Y \end{bmatrix}, \sigma_{s=2} = \begin{bmatrix} \sigma_T^X \\ \sigma_C^Y \end{bmatrix}, \sigma_{s=3} = \begin{bmatrix} \sigma_C^X \\ \sigma_T^Y \end{bmatrix}, \sigma_{s=4} = \begin{bmatrix} \sigma_C^X \\ \sigma_C^Y \end{bmatrix} \right\} \quad (3)$$

and:

$$\rho = \left\{ \rho_{s=1} = \rho_{TT}^{XY}, \rho_{s=2} = \rho_{TC}^{XY}, \rho_{s=3} = \rho_{CT}^{XY}, \rho_{s=4} = \rho_{CC}^{XY} \right\}. \quad (4)$$

Symbol T denotes the state of tranquility in the respective (banking or real) sector of the economy and symbol C denotes the crisis state.

Since we want to control for exogenous shocks to credit and output, we regress real credit growth and real output growth on a set of explanatory variables and use residuals from these regressions as our measures of X and Y. The exogenous variables employed in the analysis are explained in empirical results.

2.2. The tests of causality and independence

We model the sequence of entering the crisis and tranquil states for the banking and real sector. The banking sector and the real sector may enter crisis and calm states independently, credit may lead output, or output may lead credit into one of the regimes. We consider three types of inter-sector dependencies, i.e. causality, “strong” form of causality, and regime-independence.

We understand causality in the Granger sense as evidence that the probability of variable X (or variable Y) entering the specific state depends on past information about the states of X and Y (Granger 1980). In our Markov switching model, the distribution of a process generating the state of X (or Y) at time t depends on the state of Y (or X, respectively) at time t–1, as in Białkowski, Bohl and Serwa (2006). Therefore, we call such a dependence “regime-causality”.

The strong form of causality is present when Y (X) always enters the specific state if X (Y) was in that state one period earlier (Sola, Spagnolo and Spagnolo 2002). Regime-independence is defined as the setting, where the states of X and Y change independently.

The appropriate tests for particular inter-sector relationships are constructed by restricting the transition matrix P (e.g. Phillips 1991). For example, when the independent regime switching of the two variables *X* and *Y* is considered, the transition matrix takes the form:

$$P = \begin{pmatrix} \pi_{TT}^{X}\pi_{TT}^{Y} & \pi_{TT}^{X}(1-\pi_{TT}^{Y}) & (1-\pi_{TT}^{X})\pi_{TT}^{Y} & (1-\pi_{TT}^{X})(1-\pi_{TT}^{Y}) \\ \pi_{TT}^{X}(1-\pi_{CC}^{Y}) & \pi_{TT}^{X}\pi_{CC}^{Y} & (1-\pi_{TT}^{X})(1-\pi_{CC}^{Y}) & (1.-\pi_{TT}^{X})\pi_{CC}^{Y} \\ (1-\pi_{CC}^{X})\pi_{TT}^{Y} & (1-\pi_{CC}^{X})(1-\pi_{TT}^{Y}) & \pi_{CC}^{X}\pi_{TT}^{Y} & \pi_{CC}^{X}(1-\pi_{TT}^{Y}) \\ (1-\pi_{CC}^{X})(1-\pi_{CC}^{Y}) & (1-\pi_{CC}^{X})\pi_{CC}^{Y} & \pi_{CC}^{X}(1-\pi_{CC}^{Y}) & \pi_{CC}^{X}\pi_{CC}^{Y} \end{pmatrix}, \quad (5)$$

where π_{ij}^{Q} denotes the probability of entering the state j by the time series Q at time t, when it was in the state i at time $t-1$. $Q \in \{X, Y\}$, $i, j \in \{T, C\}$, and T and C denote the calm and crisis regimes, respectively. It should be noted that regime-independence does not imply independence of X and Y since they are still allowed to be correlated with each other.

Under the regime-causality hypothesis, the probability of variable *Y* entering the specific state of calm or crisis may depend on the state of variable *X* in the previous period. For example, weaker credit market conditions during the banking crisis may increase the probability of recession in the economy in the next period. In contrast, the variable *X* will not lead the variable *Y* into one of the regimes when the following restrictions are imposed on the transition matrix:

$$P = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{42}+p_{44}-p_{24} & p_{41}+p_{43}-p_{21} & p_{24} \\ p_{31} & p_{12}+p_{14}-p_{34} & p_{11}+p_{13}-p_{31} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{pmatrix}. \quad (6)$$

These restrictions are equivalent to the following conditions:

$\Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in crisis}) = \Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in calm})$,

$\Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in crisis}) = \Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in calm})$,

$\Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in crisis}) = \Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in calm})$,

$\Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in crisis}) = \Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in calm})$.

We can also analyse a more restrictive ("strong") form of causality between the variables *X* and *Y* when *Y* always enters the specific state if *X* was in that state one period earlier (Sola, Spagnolo and Spagnolo 2002). For example, the credit market may always follow the real sector into recession with one period delay. Then, the transition matrix equals:

$$P = \begin{pmatrix} p_{11} & 0 & 1-p_{11} & 0 \\ p_{21} & 0 & 1-p_{21} & 0 \\ 0 & p_{32} & 0 & 1-p_{32} \\ 0 & p_{42} & 0 & 1-p_{42} \end{pmatrix}. \tag{7}$$

The restrictions in the transition matrix translate into the following conditions:

$\Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in calm}) = 1$,

$\Pr(Y_t \text{ in calm} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in calm}) = 1$,

$\Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in calm and } X_{t-1} \text{ in crisis}) = 1$,

$\Pr(Y_t \text{ in crisis} \mid Y_{t-1} \text{ in crisis and } X_{t-1} \text{ in crisis}) = 1$.

We also consider asymmetric types of relationships between credit and output, where the relationship changes when the appropriate variable *X* or *Y* switches into the other state. For example, the first (latter) two rows of the transition matrix (7) correspond with *X* being in the calm (crisis) state in the previous period. Thus, it is possible to test for a "strong" form of causality from *X* to *Y* provided that *X* was in the calm (crisis) state in the previous period, by restricting only the first (latter) two rows of the transition matrix (7).

Similarly, the independence hypothesis given that *X* was in the calm (crisis) state in the previous period can be analyzed by restricting only the two first (latter) rows of the transition matrix (5). When the first and third (second and fourth) row is restricted in (5), the condition is that *Y* was in the calm (crisis) state in the previous period.

Slightly differently, there is no causality from *X* to *Y* provided that *Y* (not *X*) was in the calm (crisis) state in the previous period when the third (second) row of the transition matrix is left constrained in (6).

Combinations of these hypotheses are also possible when the appropriate rows from matrices (5), (6) and (7) are combined. However, the rows from the particular matrices must always replace rows with the same index in the combined matrix. For example, we consider the hypothesis that there is no causality from *X* to *Y* when *Y* was in the crisis regime one period earlier, and there is no regime-dependence between *X* and *Y* when *Y* was in the calm regime one period earlier. Such a hypothesis can be introduced into the model by including the second row from matrix (6), the first and third row from matrix (5) into the transition matrix *P*, and leaving the fourth row unrestricted:

$$P = \begin{pmatrix} \pi_{TT}^X \pi_{TT}^Y & \pi_{TT}^X (1-\pi_{TT}^Y) & (1-\pi_{TT}^X)\pi_{TT}^Y & (1-\pi_{TT}^X)(1-\pi_{TT}^Y) \\ p_{21} & p_{42}+p_{44}-p_{24} & p_{41}+p_{43}-p_{21} & p_{24} \\ (1-\pi_{CC}^X)\pi_{TT}^Y & (1-\pi_{CC}^X)(1-\pi_{TT}^Y) & \pi_{CC}^X \pi_{TT}^Y & \pi_{CC}^X (1-\pi_{TT}^Y) \\ p_{41} & p_{42} & p_{43} & p_{44} \end{pmatrix}. \quad (8)$$

All restrictions in the transition matrices (5), (6), (7), and (8) of our Markov switching model are tested using the likelihood ratio (*LR*) test, where the log-likelihood value from the model with the unrestricted transition matrix (1), $l_{unrestricted}$ is compared with the log-likelihood of the restricted model, $l_{restricted}$:

$$LR = 2(l_{unrestricted} - l_{restricted}) \sim \chi^2(k)\,. \quad (9)$$

Under the null hypothesis of no restrictions (equation 1), the *LR* statistic is distributed as chi-squared with *k* degrees of freedom, where *k* equals the number of independent restrictions (e.g. Sola, Spagnolo and Spagnolo 2002).

3. Empirical results

3.1. Data

Our analysis covers the sample of 103 banking crises in developed and developing economies. The crises come from the electronic database prepared by Caprio and Klingebiel (2003) who define banking crises as "much or all of bank capital being exhausted". Such crises typically comprise large-scale bank failures, depositor runs, the high level of non-performing loans, or some emergency actions of the government, i.e. deposit freezes, nationalizations, recapitalization plans, etc. (e.g. Demirgüç-Kunt, Detragiache and Gupta, 2006). The database of Caprio and Klingebiel provides the approximate starting dates and in most cases the ending dates of crises, but the authors argue that these dates are often difficult to determine and may not be accurate (see Table 1).

We use the time series of annual data beginning four years before the approximate start of each crisis and ending four years after the start of each crisis, because we focus on the periods immediately surrounding the crises and want to minimize the effects of other factors, such as long-run business and credit cycles, on credit and output growth.[2] Altogether there are 824 panel observations of real credit growth and real output growth. The real credit growth is

[2] We do not use quarterly data, because we expect lagged dependencies of order higher than one when using such data. The Markov-switching model and our tests are designed to test for lagged dependencies of order one. Additionally, the quarterly seasonality of output growth and credit growth complicates analyses of causality between credit and output, because periods of prosperity and stagnation, and seasonal patterns of output and credit growth may be difficult to differentiate in our four-regime setting.

measured as log changes in the ratio of domestic credit (line 32 in the IFS database from the International Monetary Fund) to consumer price index (line 64 in the IFS database) and the real output growth equals the log changes in the ratio of GDP (line 99b in the IFS database) to GDP deflator (line 99bip).

Instead of considering fixed or random effects in our panel dataset, which could significantly complicate our analysis, we use changes in the real effective exchange rate, the level of market interest rate, and suitable measures of financial, economic, and political development as our control variables explaining differences in dynamics of credit and output growth in different countries. The measure of financial development is the ratio of deposits to money supply in each country, averaged over the pre-crisis and crisis period. The political development measure, obtained from the POLITY IV database, is an indicator of the level of democracy for each country and year.[3] Similarly, Gross National Income per capita for each country from the year 1975, obtained from the World Bank database, is used as a proxy for the long-term level of economic development. All variables except the latter two use data from the IFS database of the International Monetary Fund.

3.2. Testing the hypotheses

We empirically investigate the relationship between real credit growth and real output growth during banking crises. We rely on the Markov-switching mixture of normal distributions to identify the periods of calm and crisis for both variables. For the credit growth and the output growth, the crisis regime is defined as a state with a lower mean value, nevertheless the volatility in this state is always higher than in the calm regime. We start with estimating the twenty specifications of our model, which correspond to different restrictions in the transition matrix and directions of causality. These specifications are equivalent to different hypotheses of no-causality, “strong” causality and regime-independence, and are presented in the first column of Table 3.

We use the general-to-specific approach to find the final specification of our model, as described in Białkowski, Bohl and Serwa (2006). When the hypotheses are not nested or the tests do not give an unequivocal answer, the Bayesian information criterion (BIC) is used to select between different specifications. The likelihood ratio statistics are employed to test the

[3] The POLITY IV database is maintained through a partnership between the University of Maryland’s Center for International Development and Conflict Management and the George Mason University Center for Global Policy.

restrictions of regime-independence (equation 5), no causality (equation 6), and "strong" causality (equation 7) against the hypothesis of bilateral causality (equation 1).

Each specification of our model is estimated in five different versions denoted as Model 1 to Model 5. In Model 1, the explained variables *X* and *Y* are the growth rates of real credit and real output. In Model 2, we first regress the explained variables on the three measures of financial, political and economic development and then use residuals from these regressions as dependent variables in the Markov switching model.

In Model 3, we include market interest rates and changes in the real effective exchange rate as additional explanatory variables and proceed as with Model 2. The data samples in Model 2 (728 observations of each variable) and Model 3 (616 observations) are shorter than the sample in Model 1 (824 observations) due to the lack of some observations in explanatory variables. Model 4 is the same as Model 1, but a shorter sample is taken from Model 3 in order to check if a lower number of observations change our results. Model 5 (680 observations of each variable) uses changes in the real effective exchange rate and changes in market interest rates as the only explanatory variables.

The initial results from estimation of regressions in Models 1 to 5 are presented in Table 2. We find that the financial and economic development measures, the market interest rate and the constant term are always significant in credit and output equations. The political regime is important only for the growth of credit and changes in the real effective exchange rate are never significant in our regressions.

The original observations of real credit growth and real output growth in Models 1 and 4, and residuals from regressions in Models 2, 3 and 5 are then used in estimations of our Markov-switching models and tests of the no-causality and independence hypotheses, as shown in Table 3. The investigated hypotheses are explained in the first column of Table 3. The degrees of freedom, used in the likelihood ratio (*LR*) tests of corresponding hypotheses, are reported in the second column. In the next columns, the values of the *LR* test and *BIC* are presented for each version and specification of the model.

From the reported results we find that the hypotheses of "strong" causality are uniformly rejected across different versions of our model. Furthermore, the hypothesis of no causality is never rejected, which suggests that neither credit leads output nor output leads credit in any regime. It means that information about the actual state of output growth does not help explaining the future state of credit growth and the credit growth is not useful in predicting output growth. This result is also robust to different combinations of explanatory variables in Models 1 to 5.

The regime-independence hypothesis is marginally rejected in Model 1 and it is not rejected in Models 2 to 5. Additionally, the information criterion suggests that the best model is the one indicating regime-independence between credit and output in both regimes of calm and crisis. However, the second best model is the less restrictive specification indicating no regime-dependence when one of the variables is in the crisis regime, and no causality but instantaneous regime-dependence between credit and output when that variable is in the calm regime. The regime-independence only in the situation when credit growth was in the calm regime one period earlier is rejected in more instances.

These outcomes suggest that there is some evidence of instantaneous regime-dependence between the analyzed variables. Credit and output may often enter the crisis and calm regimes at the same time when they both are in the calm regime one period earlier.

Another result is that the likelihood ratio values also depend on the number of observations (and crises). When the number of observations is low, as in Models 3 and 4, the *LR* tests may fail to distinguish between opposite specifications. For example, the hypothesis of regime-independence is not rejected and the hypothesis of "strong" causality from output to credit in the crisis regime is only marginally rejected in Model 4. Therefore, we proceed with Model 1 employing the largest number of observations in our further analysis.[4]

Table 4 presents parameters of the final Model 1, satisfying the hypothesis of no regime-dependence in times of crisis and no causality from output to credit in the calm regime, i.e. the second best (and less restrictive) specification, as explained above. In the crisis regimes, the mean credit growth and the mean output growth are significantly lower than in the calm regimes. The rate of real credit growth drops by about 8 percentage points annually and the rate of annual real growth slows down by 5 percentage points during crises. An additional cost of banking crises is the volatility of both variables that increases almost twenty fold in times of turbulence.

What is important, the covariance between credit and output is significant in each regime, which points to the presence of conditional linear relationship between these variables in calm and crisis regimes. This relationship is regime-dependent, because the sign of the covariance changes between regimes. The correlation is usually positive, but it becomes negative when credit is in the calm state and output enters the crisis state. The banking sector

[4] In order to examine how our model fits the data we use tests proposed by Breunig, Najarian, and Pagan (2003) and confirm that the parameters of sample means and variances simulated from our model are consistent with the original data. Detailed results are available upon request.

loses its positive link with the real economy usually in those situations when it precedes the real sector in leaving the crisis regime during the turmoil, i.e. in the third regime.

From the estimated parameters in the transition matrix one can infer that all four regimes are quite persistent. Once credit and output enter one of these regimes, they stay there for a longer period, as indicated by the values on the diagonal of the transition matrix.

All regimes together reveal some interesting patterns of shock transmission between the banking sector and the real economy (Figure 1). There is only a small probability (0.124) that credit and output will leave the first regime, where both variables are in the calm state. When they leave that regime, they usually enter the fourth state of the Markov switching model, where both variables are in the crisis regime. The banking and the real sector enter the crisis simultaneously, which confirms our previous result of no causality between output and credit.

From the fourth state the credit and the output most often enter the second regime, less likely the third regime, and rarely the first regime. In the second regime, output growth is in the calm state, while the banking sector still suffers from the crisis. This suggests that the real sector is the first to shake off the banking crisis and the crises may have shorter-term effects on output growth than on credit market conditions. Since the most often visited regime, when leaving the second regime, is the first one, we can infer that both sectors usually finish in the state of calm.

Similarly, when credit and output are in the third regime, where the credit market raises and the real sector experiences turbulences, the next most likely step for the system is to enter the first regime. This result can be interpreted in the way that the depressed real sector rarely initiates a banking crisis in the next period.

4. Conclusions

This paper proposes a new methodology to test for nonlinear linkages between the banking and real sector during banking crises. While employing a variety of tests we observe no significant causality between output growth and credit growth in times of banking crises, even after controlling for the impact of measures of financial, political, economic development and changing interest and foreign exchange rates. Instead, some specifications reveal a nonlinear instantaneous relationship between the analyzed variables when credit or output is in the calm state. This relationship is asymmetric and depends on the state of one of the variables.

In addition, there is a linear instantaneous relationship between credit and output, as indicated by the significant covariances between credit and output growth in each regime. However, this relationship is also regime-dependent. Most of the time the covariance is positive, but it becomes negative when the real sector enters the recession and the credit sector expands. This result confirms the statement from our introduction that banking crises impact the link between credit and output.

The report about the real credit growth reduced by 8 percentage points and the real output growth reduced by 5 percentage points annually during crisis periods, together with the results indicating the significantly increased volatility of both variables, corroborate earlier outcomes pointing to large costs suffered by economies around banking crises. These outcomes certainly do not show that the whole reduction in output growth is caused by the declining credit growth, because there are other exogenous variables contributing to these changes. Nevertheless, the analyzed sample, closely linked to periods of banking crises, increases the likelihood that the banking sector significantly affects economic activity.

Although our empirical model fits well the theoretical construction proposed by Azariadis and Smith (1998), the presented results are not meant to prove that shifts in regimes of output growth are solely due to credit-rationing conditions and future studies may show how other factors influence the changing regimes in real sectors. Our results illustrate the dynamics and interdependencies between credit and output around banking crises.

Some versions of the proposed Markov switching model can be employed for practical purposes. An appropriate specification of the transition matrix in this model makes it possible to estimate the probabilities of entering the specific states of calm or crises by the credit and output variables. International investors can employ analogous models to estimate more accurately output growth in countries facing financial crises. Banking sector authorities can calculate the probabilities of financial instability, given the actual state of the real and financial sectors. The results obtained from the estimation of the transition matrix enable economists to better understand the behavior of the banking and real sectors of the economy during crises, i.e. the sequence of entering the specific regimes of calm and crisis.

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Table 1: Analyzed periods around banking crises

Developed countries:		
Australia 1985-1992 (1989)	Spain 1973-1980 (1977)	Japan 1987-1994 (1991)
Canada 1979-1986 (1983)	Sweden 1987-1994 (1991)	Korea 1993-2000 (1997)
Denmark 1983-1990 (1987)	Hong Kong 1994-2001 (1998)	New Zealand 1983-1990 (1987)
Finland 1987-1994 (1991)	Iceland 1981-1988 (1985)	United Kingdom 1970-1977 (1974)
Germany 1973-1980 (1977)	Iceland 1989-1996 (1993)	United Kingdom 1986-1993 (1990)
Greece 1987-1994 (1991)	Italy 1986-1993 (1990)	United States 1982-1990 (1986)
Norway 1983-1990 (1987)		
Developing countries:		
Algeria 1986-1993 (1990)	El Salvador 1985-1992 (1989)	Papua New Guinea 1984-1991
Argentina 1976-1983 (1980)	Ethiopia 1990-1997 (1994)	(1988)
Argentina 1985-1992 (1989)	Gabon 1991-1998 (1995)	Paraguay 1991-1998 (1995)
Argentina 1997-2004 (2001)	Gambia 1981-1988 (1985)	Peru 1979-1986 (1983)
Benin 1984-1991 (1988)	Ghana 1978-1985 (1982)	Philippines 1977-1984 (1981)
Bolivia 1982-1989 (1986)	Hungary 1987-1994 (1991)	Philippines 1994-2001 (1998)
Bolivia 1990-1997 (1994)	India 1989-1996 (1993)	Poland 1989-1996 (1993?)
Botswana 1990-1997 (1994)	Indonesia 1990-1997 (1994)	Romania 1986-1993 (1990)
Brazil 1986-1993 (1990)	Indonesia 1993-2000 (1997)	Russia 1994-2001 (1998)
Brazil 1990-1997 (1994)	Israel 1973-1980 (1977)	Rwanda 1987-1994 (1991)
Burkina Faso 1984-1991 (1988)	Jamaica 1990-1997 (1994)	Senegal 1984-1991 (1988)
Burundi 1990-1997 (1994)	Jordan 1985-1992 (1989)	Sierra Leone 1986-1993 (1990)
Cameroon 1983-1990 (1987)	Kenya 1981-1988 (1985)	Singapore 1978-1985 (1982)
Central African Republic 1984-	Kenya 1988-1995 (1992)	South Africa 1973-1980 (1977)
1991 (1988)	Kenya 1992-1999 (1996)	South Africa 1985-1992 (1989)
Chad 1988-1995 (1992)	Kuwait 1976-1983 (1980?)	Sri Lanka 1985-1992 (1989)
Chile 1972-1979 (1976)	Lesotho 1984-1991 (1988)	Tanzania 1985-1992 (1989?)
Chile 1977-1984 (1981)	Madagascar 1984-1991 (1988)	Thailand 1979-1986 (1983)
Colombia 1978-1985 (1982)	Malaysia 1981-1988 (1985)	Thailand 1993-2000 (1997)
Congo, Democratic Republic of	Malaysia 1993-2000 (1997)	Togo 1989-1996 (1993)
(former Zaire) 1987-1994 (1991)	Mauritius 1992-1999 (1996)	Tunisia 1987-1994 (1991)
Congo, Republic of 1988-1995	Mexico 1977-1984 (1981)	Turkey 1978-1985 (1982)
(1992)	Mexico 1990-1997 (1994)	Turkey 1990-1997 (1994)
Costa Rica 1983-1990 (1987?)	Morocco 1977-1984 (1981?)	Turkey 1996-2003 (2000)
Costa Rica 1990-1997 (1994)	Myanmar 1992-1999 (1996)	Ukraine 1993-2000 (1997)
Cote d'Ivoire 1984-1991 (1988)	Nepal 1984-1991 (1988)	Uruguay 1977-1984 (1981)
Ecuador 1978-1985 (1982?)	Niger 1979-1986 (1983)	Venezuela 1976-1983 (1980?)
Ecuador 1987-1994 (1991)	Nigeria 1989-1996 (1993)	Venezuela 1990-1997 (1994)
Ecuador 1994-2001 (1998)	Panama 1984-1991 (1988)	Zimbabwe 1991-2008 (1995)
Egypt 1987-1994 (1991)		

Note: The probable starting dates of banking crises, provided in Caprio and Klingebiel (2003), are presented in parentheses. These probable starting dates are used to construct samples around banking crises in our analysis. The symbol "?" denotes the most likely starting date of a banking crisis when the exact year was not given in Caprio and Klingebiel (2003).

Table 2: Controlling for various dependencies in the regressions of credit growth and output growth

	Model 1	Model 2	Model 3	Model 4	Model 5
Explained variable: real output growth					
const	0.024*** (0.003)	0.043*** (0.007)	0.052*** (0.006)	0.028*** (0.004)	0.039*** (0.004)
financial development		-0.063*** (0.018)	-0.060** (0.025)		
economic development		-0.248*** (0.079)	-0.368*** (0.091)		
political development		0.245 (0.469)	0.407 (0.592)		
changes in REER			0.018 (0.026)		0.017 (0.022)
interest rate			-0.347*** (0.082)		-0.572*** (0.082)
number of observations	824	728	616	616	680
R^2	0.00	0.02	0.03	0.00	0.04
DW	1.35	1.50	1.47	1.54	1.36
explained variable: real credit growth					
const	0.025** (0.010)	0.091*** (0.021)	0.123*** (0.023)	0.032*** (0.010)	0.070*** (0.013)
financial development		-0.354*** (0.094)	-0.390*** (0.094)		
economic development		0.965*** (0.314)	0.674* (0.375)		
political development		-5.422*** (1.366)	-5.279*** (1.277)		
changes in REER			0.062 (0.105)		0.123 (0.116)
interest rate			-0.977* (0.564)		-1.801*** (0.523)
number of observations	824	728	616	616	680
R^2	0.00	0.06	0.07	0.00	0.04
DW	1.44	1.62	1.63	1.44	1.48

Note: Standard errors in parentheses. Symbols *, **, *** indicate significance of the parameter at the 10%, 5% and 1% level, respectively.

Table 3: Testing restrictions in the credit-output relationship

		Model 1		Model 2		Model 3		Model 4		Model 5	
Hypothesis	d.f.	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*
testing for no-causality											
no causality from credit to output	2	0.4	-1.560	0.6	-1.626	0.9	-1.604	1.0	-1.636	4.0	-1.522
no causality from output to credit	2	0.7	-1.559	1.5	-1.625	4.0	-1.598	2.3	-1.634	4.4	-1.521
no causality from credit to output when output in crisis	1	0.0	-1.552	0.3	-1.618	0.1	-1.594	0.2	-1.627	0.0	-1.518
no causality from output to credit when credit in crisis	1	0.3	-1.552	0.7	-1.617	1.4	-1.592	0.0	-1.627	0.9	-1.517
no causality from credit to output when output in calm	1	0.4	-1.552	0.5	-1.617	0.3	-1.594	0.3	-1.626	0.1	-1.518
no causality from output to credit when credit in calm	1	0.5	-1.551	1.2	-1.616	0.7	-1.593	0.0	-1.627	0.6	-1.517
testing for strong form of causality											
strong causality from credit to output	8	68.2***	-1.526	60.2***	-1.599	61.8***	-1.567	60.7***	-1.601	63.2***	-1.492
strong causality from output to credit	8	55.6***	-1.542	55.2***	-1.606	58.2***	-1.573	41.2***	-1.633	62.6***	-1.493
strong causality from credit to output when credit in crisis	4	58.4***	-1.506	55.1***	-1.569	58.9***	-1.530	56.3***	-1.567	60.1***	-1.458
strong causality from output to credit when output in crisis	4	16.2***	-1.557	14.7***	-1.625	12.6**	-1.605	8.5*	-1.644	19.7***	-1.518

Note: Model 1 is the model of real credit growth and real output growth with no additional explanatory variables; Model 2 is the model with the measures of financial, political and economic development as explanatory variables; Model 3 is the model with changes in real effective exchange rate, changes in market interest rates, and the measures of financial, political and economic development as explanatory variables; Model 4 is the model with no additional explanatory variables, but using a smaller sample of countries (the same as in Model 3); Model 3 is the model with changes in real effective exchange rate, changes in market interest rates as explanatory variables. Symbol d.f. denotes degrees of freedom in the chi-squared distribution related to the appropriate hypothesis. LR is the value of the likelihood ratio statistic and BIC is the Bayesian information criterion. Symbols *, **, *** indicate rejection of the null hypothesis (reported in the first column) at the 10%, 5% and 1% significance level, respectively.

Table 3 continued: Testing restrictions in the credit-output relationship

		Model 1		Model 2		Model 3		Model 4		Model 5	
Hypothesis	d.f.	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*	*LR*	*BIC*
testing for regime-independence											
no regime-dependence between credit and output	8	13.8*	-1.592	8.9	-1.669	5.5	-1.659	7.6	-1.687	7.7	-1.574
no regime-dependence between credit and output when output in crisis	3	1.9	-1.566	3.9	-1.631	1.7	-1.613	0.6	-1.647	1.5	-1.535
no regime-dependence between credit and output when credit in crisis	3	1.1	-1.567	2.6	-1.633	2.3	-1.612	1.0	-1.646	1.2	-1.535
no regime-dependence between credit and output when output in calm	3	7.0*	-1.560	5.1	-1.629	4.0	-1.609	4.7	-1.640	6.3*	-1.528
no regime-dependence between credit and output when credit in calm	3	11.4***	-1.555	8.3**	-1.625	4.9	-1.607	6.8*	-1.637	6.2	-1.528
testing for mixtures of no-causality and regime-independence											
no causality from credit to output when output in crisis and no regime-dependence between credit and output when output in calm	4	8.0*	-1.567	5.9	-1.637	4.4	-1.619	5.1	-1.650	6.6	-1.537
no causality from output to credit when credit in crisis and no regime-dependence between credit and output when credit in calm	4	11.3**	-1.563	8.3*	-1.634	5.3	-1.617	6.8	-1.647	6.4	-1.537
no causality from credit to output when output in calm and no regime-dependence between credit and output when output in crisis	4	2.0	-1.574	4.1	-1.640	2.0	-1.623	0.7	-1.657	1.6	-1.544
no causality from output to credit when credit in calm and no regime-dependence between credit and output when credit in crisis	4	1.3	-1.575	3.6	-1.640	2.3	-1.622	0.9	-1.657	1.9	-1.544

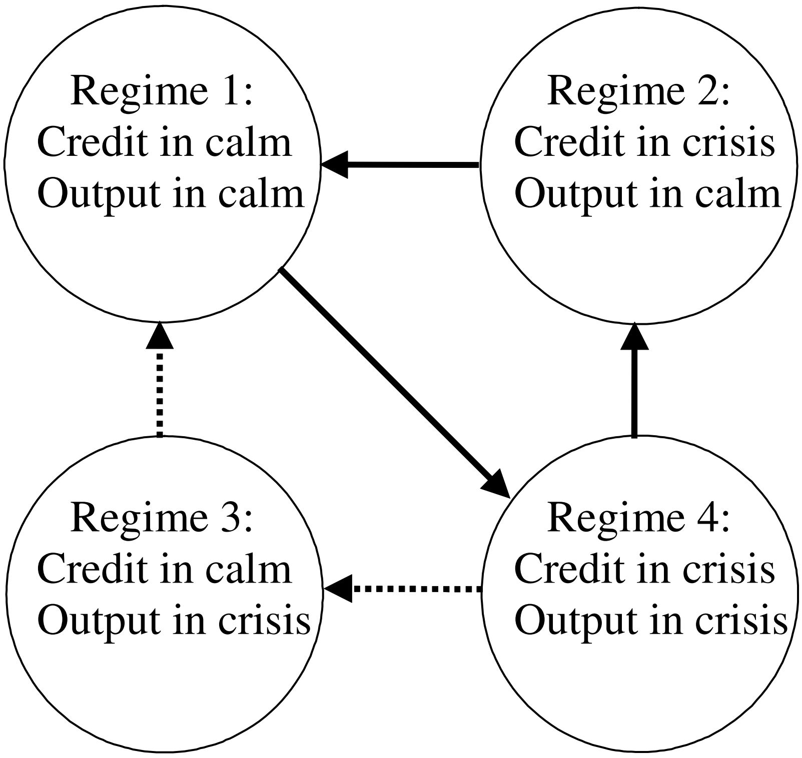
Note: See Table 3.

Table 4: Final model of dependencies between credit growth and output growth

Regime of output growth (*X*)	Regime of credit growth (*Y*)	μ^X	μ^Y	σ^X	σ^Y	cov(*X*,*Y*)	corr(*X*,*Y*)	Transition matrix *P*			
Calm	Calm	0.0337 (0.0021)	0.0516 (0.0061)	0.0010 (0.0001)	0.0073 (0.0008)	0.0011 (0.0002)	0.391	0.876	0.036	0.020	0.068
Calm	Crisis	0.0337 (0.0021)	-0.0288 (0.0350)	0.0010 (0.0001)	0.1419 (0.0206)	0.0019 (0.0019)	0.156	0.197	0.719	0.018	0.066
Crisis	Calm	-0.0150 (0.0164)	0.0516 (0.0061)	0.0195 (0.0036)	0.0073 (0.0008)	-0.0093 (0.0020)	-0.782	0.380	0.018	0.517	0.103
Crisis	Crisis	-0.0150 (0.0164)	-0.0288 (0.0350)	0.0195 (0.0036)	0.1419 (0.0206)	0.0160 (0.0075)	0.304	0.075	0.274	0.140	0.511
Log-likelihood	715.98										
Number of observations	824										

Note: Symbols cov(*X*,*Y*) and corr(*X*,*Y*) denote covariance and correlation between *X* and *Y*, respectively. Standard errors in parentheses.

Figure 1: The most likely sequence of entering the specific regimes by credit and output



Note: Solid arrows point to the most likely scenario. Dotted arrows indicate the less likely scenario.