ARE PRIVATE SMEs FINANCIALLY CONSTRAINED DURING THE CRISIS? EVIDENCE FROM THE ITALIAN MARKET

Abstract

On the basis of a large panel data set of Italian private SMEs, this paper estimates a disequilibrium model of demand and supply of credit in the period 2007-2011. We find that private Italian SMEs have been credit rationed during the crisis, especially in the years 2007, 2008 and 2011. On the demand side, firms which requested more bank credit are smaller companies, showing higher increase in working capital, fewer available internal sources and fewer substitutes for bank finance. On the supply side, banks reduced lending more to the smaller, riskier and highly indebted firms. Financial companies preferred to allocate new credit to SMEs which could offer collateral and showed higher increase in sales. Surprisingly, older firms have been more financially constrained than the younger ones. We also find that banks consider a strong ownership concentration a negative element in deciding for lending.

Keywords: financial crisis, credit lending, credit demand, financial constraints, SMEs

JEL Classification: E51, G01

1. Introduction

The financial crisis which erupted in September 2008 with the collapse of Lehman Brothers has quickly turned into an economic crisis. The financial sector is closely linked to the real one, as banks are an important source of funding for firms. This is especially true in the Eurozone, where capital markets are relatively undeveloped compared to the USA and there are many small and medium enterprises (SMEs). Most of European financial systems are in fact intermediary-oriented rather than market-oriented.

Since 2008 there has been an intense debate on whether European banks have reduced lending to firms. Because of its important implications, this debate has involved not only economists, but also politicians and the public opinion at large. The discussion is not about the fact that SMEs have received less credit from banks during the crisis than in the past, but on why it happened. In other words, have European banks reduced lending to firms or have enterprises cut their credit demand? This paper tries to answer these questions focusing on the Italian market in the period 2007-2011.

From a theoretical point of view, the sudden dry up in bank liquidity could have affected the availability of credit by firms. A drop in liquidity for banks may have impacted the supply of credit for enterprises, especially for those unable to access other external sources of funds than banks, such as trade credit or financial markets. This is particularly relevant for private Italian SMEs, as their opacity makes it difficult to access funds from other sources.

On the other hand, firms might also have reduced their demand for credit. Since 2008 Italian companies have experienced progressive reductions in sales, profitability and cash flows. In 2012 the balance between profitable and non-profitable firms remained below pre-crisis levels by more than 10 percentage points. The companies most affected by decline in profits were the smaller ones. The financial difficulties related to the reduction of income were associated with an abrupt lengthening of payment terms by customers. This led many enterprises in turn, to delay payments to suppliers. Shock, which was large and persistent, has come to represent one of the main channels of transmission of liquidity strains within the production system. The weak accumulation of capital could have decisively contributed to limiting the financing needs of companies.

Existing literature has investigated whether reductions in credit lending during the recent crisis were caused by demand-side or supply-side factors. Some authors (Albertazzi and Marchetti, 2010; Puri et al., 2011; Jimenez et al., 2012; Iyer et al., 2013) suggest that reductions in business lending during the financial crisis were predominantly caused by supply effects, while other studies (Kremp and Sevestre, 2012; Rottmann and Wollmershauser, 2013) show that reductions in SME lending were mainly caused by demand-side factors. Finally, Popov and Udell (2010) and Presbitero, Udell and Zazzaro (2012) find that both demand and supply factors led to lower SME lending in European countries in the financial crisis.

These empirical results conflict and do not point to conclusive evidence of a capital-related contraction of credit supply in Europe during the recent crisis. The identification of changes in credit supply is particularly difficult because of the necessity to take into account credit demand changes (Udell, 2009; Albertazzi and Marchetti, 2010).

Our paper tries to overcome this gap and empirically investigate the existence of credit rationing in the Italian corporate bank loan market by estimating the demand-supply disequilibrium model for bank credit. From this model we derive the proportion of credit rationed companies using a panel data set of private Italian SMEs for the period 2007-2011.

This study contributes to previous literature in different points. First, our paper is the first to investigate the Italian credit market during the recent crisis by applying a disequilibrium model. Second, this study is one of the few using a large sample of private SMEs, and to take

into account 2011. Third, to our knowledge, this is the first paper to study the relationship between concentrated ownership and credit rationing.
The remainder of the paper is organized as follows: the literature on credit rationing is summarized in Section 2; the methodology and the sample are described in Sections 3 and 4. The results are discussed in Section 5. Lastly, the conclusions of the study are presented in Section 6.

2. Literature review

The literature on credit rationing is mainly based on the assumption of the existence of asymmetric information between borrowers (firms) and lender (banks). In an equilibrium with credit rationing, demand exceeds supply at the current interest rate, and the result is a situation of under-investment by firms.
Many studies on credit rationing indicate that small and medium enterprises (SMEs) are the most prone to this phenomenon (Fazzari et al., 1988; Calomiris and Hubbard, 1990; Gertler and Gilchrist, 1994). This can be theoretically explained considering that: (i) the information asymmetry between borrower and lender is greater in SMEs than in large firms; (ii) SMEs are characterized by high monitoring costs (Williamson, 1987); (iii) small firms have higher failure rates than large ones (Hall, 1992).
Credit rationing is often a problem for SMEs, for which the banking system plays a crucial role in the provision of external finance (Bernanke and Bliender, 1988; Kasyap and Stein, 1994; Berger and Udell, 2005; Bougheas et al., 2006). Since SMEs are often unable to access other markets for funds, banks are their main external source of funds (Berger and Udell, 1998; Robb and Robinson, 2009) helping them to substitute expensive trade credit (Petersen and Rajan, 1997; Fisman and Love, 2003; Canales and Nanda, 2011).
The recent international financial crisis has made the issue of credit rationing to SMEs dramatically important. Some authors have studied this phenomenon in Europe, trying to investigate whether reductions in lending were caused by demand-side or supply-side factors. On the one hand, credit supply is affected by the banks' balance-sheet strength, the so-called *bank lending channel* (Bernanke and Gertler, 1995; Holmstrom and Tirole, 1997; Adrian and Shin, 2010). On the other hand, demand is affected by the firm balance-sheet strength, the so-called *firm balance-sheet channel* (Bernanke and Gertler, 1995; Bernanke, Gertler and Gilchrist, 1996).
Different strategies have been used in the literature in order to identify supply shock.
One strategy consists of using credit registry data on firms that have multiple lenders (Albertazzi and Marchetti, 2010; Puri et al., 2011; Jimenez et al., 2012; Iyer et al., 2013).
Jimenez, Ogena, Peydro and Saurina (2012) find evidence showing that heterogeneity in Spanish bank balance-sheet strength does not determine loan granting in good times, but in crisis times it does. In contrast, when analyzing the effect of firm balance-sheet strength on loan granting, the authors show that Spanish firm heterogeneity in balance-sheet strength determines the probability a loan is granted to the applying firm in both good and crisis times. Jimenez, Ogena, Peydro and Saurina (2012) therefore suggest that reductions in business lending in Spain during the financial crisis were predominantly caused by supply effects.
Puri, Rocholl J. and Steffen (2011) reach the same results studying the crisis effects in Germany in the period 2006-2008. They find evidence of a significant supply side effect in that smaller and more liquidity-constrained saving banks rejected substantially more loan applications than other saving banks.
Iyer, Lopes, Peydro and Schoar (2013) reach the same conclusions analyzing the effects of the 2007-2009 financial crisis on the supply of credit to SMEs in Portugal. Their results suggest that the decrease in lending affected small firms most severely, while larger more established firms were less affected.

Albertazzi and Marchetti (2010) show evidence of a contraction of credit supply in the Italian credit market in the period September 2008-March 2009. Quite strikingly, they find that larger less-capitalized banks reallocated their credit away from riskier firms (the so-called "*flight to quality effect*"), but smaller less-capitalized banks did not.
A second approach to identify supply shock is to use survey data that contain information on loan applications (Popov and Udell, 2010, 2012; Presbitero et al., 2012; Rottmann and Wollmershauser, 2013).
Popov and Udell (2010) find that both factors led to lower SME lending in 14 European countries in the early stage of the 2007-2008 financial crisis. The authors verify that European banks experiencing stress to their assets and equity values extended less credit and that the observed decline in credit was greater among high-risk firms and firms with fewer tangible assets. These results were confirmed by a subsequent analysis on 16 emerging European countries (Popov and Udell, 2012).
Presbitero, Udell and Zazzaro (2012) come to the same results with reference to the Italian market. They find evidence that in Italy there was a significant contraction in both demand and supply of credit in the period 2008-2009.
Rottmann and Wollmershauser (2013) find that in the period 2008-2009 only large German firms reported a very subdued willingness of the banks to grant credit. For this reason the authors argue that in Germany reductions in SME lending were caused by demand-side factors.
A third alternative approach to identify supply shock is to apply a disequilibrium model to identify credit constrained firms (Kremp and Sevestre, 2012). Kremp and Sevestre (2012), focussing on the French credit market in the period 2000-2010, show that, even since 2008, most of the observed reduction in outstanding loans is explained by the decrease in French SMEs' demand for credit, following the big decrease of their business and investment projects.
The studies described above show different results and do not yield conclusive evidence of a capital-related contraction of credit supply in Europe during the recent crisis. The identification of changes in credit supply is particularly difficult because of the necessity to take into account credit demand changes (Udell, 2009; Albertazzi and Marchetti, 2010).
Our paper tries to overcome this gap and empirically investigate the existence of credit rationing in the Italian corporate bank loan market by estimating the demand-supply disequilibrium model for bank credit. From this model, we derive the proportion of credit rationed companies using a panel data set of private Italian SMEs for the period 2007-2011.
In the study of the restrictions to credit supply, Italy is an excellent laboratory for three main reasons. First, although Italian banks have been affected by the financial crisis, their systemic stability has not been endangered (Panetta et. al., 2009; De Mitri et al., 2010). Second, among European countries, the Italian market has the largest shares of private SMEs in its economic system. Third, and most importantly, Italy is a bank-oriented economy and, for this reason, changes in credit supply could make a big impact. Lastly, thanks to economic and banking features in common, the analysis of the Italian credit market during the crisis can help us to understand the changes in continental European markets at large.
In order to investigate the demand and supply dynamics in the credit market during the crisis, this paper aims to verify the following hypothesis:

H_1: *Reduction in bank lending for Italian private SMEs during the recent crisis was caused by both demand-side and supply-side factors.*

A number of studies have tried to identify which type of firms are more exposed to credit tightening (Bagella et al., 2001; Becchetti and Trovato, 2002; Presbitero et al., 2012). Pre-crisis literature shows that SME financial constraints are inversely related to firm size (Bagella et al., 2001; Becchetti and Trovato, 2002), and directly related to firm age (Bagella et

al., 2001; Becchetti and Trovato, 2002). Are these relationships confirmed during the recent crisis? To answer these questions we verify the following hypotheses:

H_2: *Reduction in bank lending for Italian private SMEs during the recent crisis was greater for smaller companies*.

H_3: *Reduction in bank lending for Italian private SMEs during the recent crisis was greater for younger companies*.

Finally, we investigate if concentrated ownership in Italian private firms can impact their financial constraints. We test the following hypothesis:

H_4: *Reduction in bank lending for Italian private SMEs during the recent crisis was greater for concentrated ownership companies*.

The first contribution to the literature is that this is the first paper to investigate the Italian credit market during the recent crisis by applying a disequilibrium model. Second, our paper is one of the few using a large sample of private SMEs. Specifically, we focus on 142,066 non-listed companies in Italy between 2007 and 2011. Third, to our knowledge, this is the first paper in literature studying the relationship between concentrated ownership and credit rationing.

3. Methodology

We empirically investigate the existence of credit rationing in the Italian corporate bank loan market by estimating a demand-supply disequilibrium model for bank credit (Ogawa and Suzuki, 2000; Atanasova and Wilson, 2004; Carbo-Valverde et al., 2009; Kremp and Sevestre, 2012). In order to investigate the existence of credit rationing (i.e. a disequilibrium in the credit market), we estimate the following simultaneous equation model (Maddala and Nelson, 1974; Laffont and Garcia, 1977; Kremp and Sevestre, 2012): (i) a demand equation L_t^d; (ii) a supply equation L_t^s; (iii) and a transaction equation L_t.

$$L_t^d = \beta_1 x_{1t} + \varepsilon_{1t} \quad (1)$$

$$L_t^s = \beta_2 x_{2t} + \varepsilon_{2t} \quad (2)$$

$$L_t = \min (L_t^d, L_t^s) \quad (3)$$

where x_{1t} and x_{2t} are exogenous and independent variables, β_1 and β_2 are their coefficients and ε_{1t} and ε_{2t} are disturbance terms. In our model only the amount of bank credit received (L_t) is observed, while L_t^d and L_t^s are the results of estimations. Equation (3) links the observed amount of bank loans received by firms to the unobserved demand and supply. Specifically, our model assumes that the observed amount of bank credit is the minimum of supply and demand. This system of equations is estimated through the maximum likelihood method (Maddala and Nelson, 1974; Kremp and Sevestre, 2012). Further methodological details are provided in the Appendix.

The **demand** equation L_t^d (1) depends on the following variables:

1) the size of the firm: we expect that smaller companies request more bank credit than larger firms, as they are unable to access other external sources of funds than banks, such as trade credit or financial markets. We accounted for the size of the firm through the natural logarithm of its total assets (Atanasova and Wilson, 2004; Carbo Valverde et al., 2009).

2) short-term financing needs: we assume that firms showing the highest increases in working capital in the year *t* compared to year *t-1* will exhibit the greatest need for short-term credit. Following Kremp and Sevestre (2012), we proxy short-term financing needs with the increase in working capital over total assets, although most previous papers use sales to account. We calculate working capital as the sum of trade credit and inventories, net of commercial debt.

3) long-term financing needs: as suggested by Kremp and Sevestre (2012), we estimate the long-term financing needs using the amount of investment over total assets. We hypothesize that firms with greater long-term financing needs show a higher demand for bank credit.

4) internal available resources: according to the "*pecking order theory*" (Myers and Majluf, 1984; Fama and French, 2002), firms choose their financial resources following a precise order. Companies prefer internal available sources and, when these are not sufficient, they request external sources as bank credit. For this reason we assume that the demand for bank credit increases if a firm has less internal available sources. We measure internal resources by the company's cash flow over its total assets (Atanasova and Wilson, 2004; Carbo Valverde et al., 2009; Kremp and Sevestre, 2012).

5) substitute for bank finance: we assume that firms with more substitute for bank finance show a lower demand for bank credit. Other sources of external available finance are taken into account through non-bank financial debt over total assets (Kremp and Sevestre, 2012) and commercial debt over total assets (Atanasova and Wilson, 2004; Carbo Valverde et al., 2009; Kremp and Sevestre, 2012). Commercial debt allows for the role of trade credit as a cheaper and alternative source of short-term finance.

6) cost of bank debt: we expect that the demand for bank credit will decrease if the cost of bank credit is high. Following Kremp and Sevestre (2012), we measure the cost of borrowing by the ratio of interest expenses over total debt.

7) finally, we consider year dummies.

The **supply** equation L_t^s (2) depends on the following variables:

1) the size of the firm: we expect that banks have reduced lending more to smaller firms than to larger ones, as smaller firms have higher failure rates than larger ones (Hall, 1992). As for the demand function, we accounted for the size of the firm through the natural logarithm of its total assets (Atanasova and Wilson, 2004; Carbo Valverde et al., 2009).

2) firm's previous financial debt: we assume that banks were reluctant to allocate new credit to firms already heavily indebted. Firm indebtness is calculated as the ratio of financial debt to net cash flow (Kremp and Sevestre, 2012).

3) firm profitability: measured by return on equity. We expect that banks have reduced lending more to less profitable companies.

4) the age of the firm: following previous paper (Bagella et al., 2001; Becchetti and Trovato, 2002), financial constraints are assumed to be directly related to firm age, which is represented by a dummy taking value 0 for less than five year old companies, 1 otherwise (Kremp and Sevestre, 2012).

5) firm default risk: *ceteris paribus*, banks prefer to offer credit to firms characterized by low default risk degree, for which the repayment of the loans is more certain. Following Albertazzi and Marchetti (2010), we proxy the firm default risk by Altman Z-score estimated for private companies (Altman, 1968, 1977). This measure predicts the probability that a firm

will go into bankruptcy within two years. The Z-score estimated for private companies is a linear combination of five business ratios, weighted by coefficients, according to the following formula:

$$Z = 0.717x_1 + 0.847x_2 + 3.107x_3 + 0.420x_4 + 0.998x_5 \quad (4)$$

where x_1 = (current assets - current liabilities) / total assets; x_2 = retained earnings / total assets; x_3 = earnings before interest and taxes / total assets; x_4 = book value of equity / total liabilities; x_5 = sales/ total assets.

6) ability to provide collateral: we assume that banks prefer to allocate new credit to firms which can offer worth collateral, as they can have a signalling value (Bester, 1987) and reduce the information asymmetry between SMEs and financial companies (Chan and Kanatas, 1985). In case of firm default, banks can sell the collateral obtained thus recovering their loans totally or partially. The ability to provide collateral is calculated by tangible assets over total assets (Carbo Valverde et al., 2009; Kremp and Sevestre, 2012).

7) change in sales: we expect firms with bigger decrease in sales to be more financially constrained. The variable is measured by the change of natural logarithm of sales between *t* and *t-1*.

8) ownership concentration: we assume that banks prefer to allocate new credit to firms with lower concentrated ownership. Concentrated ownership in fact has negative consequences for firms, including higher cost of capital due to fewer diversification opportunities for investors (Fama and Jensen, 1983) and the possibility that large shareholders deprive small owners of their part of residual income. We measure ownership concentration by BVD Independence Ratio. This ratio, available in AIDA database, classifies firms into four groups: (i) no shareholder holding more than 25% of equity capital (independent companies); (ii) one or more shareholder holding more than 25% of equity capital, but not over 50%; (iii) more than one shareholder holding together more than 50% of equity capital (indirectly majority owned companies); (iv) at least one shareholder holding more than 50% of equity capital (directly majority owned companies). We proxy ownership concentration by a scale from 1 (independent companies) to 4 (directly majority owned companies).

8) finally, we consider year dummies.

Table 1 shows variables used in the paper.

Table 1
Definition of variables

Variables	Symbol	Definition and calculation model
Firm size	Size	This is calculated as the natural logarithm of firm's total assets
Short-term financing needs	ST_Fin	Short-term financing needs are estimated through the increase in working capital over total assets. The variable is calculated as the sum of trade credit and inventories, net of commercial debt
Long-term financing needs	LT_Fin	Calculated as the amount of firm investment over total assets
Internal available resources	Cash	Calculated as the company cash flow over total assets
Financial substitute for bank finance	Sub_f	Calculated as the firm non-bank financial debt over total assets
Commercial substitute for bank	Sub_c	Calculated as the firm commercial debt over total assets

finance		
Cost of bank debt	Int	Calculated as the ratio of firm interest expenses over total debt
Firm indebtness	Deb	Calculated as the ratio of firm financial debt to net cash flow
Firm profitability	Roe	Measured by return on equity. This is calculated as firm net income over total equity
Age of the firm	Age	Measured by a dummy taking value 0 for less than five year old companies, 1 otherwise
Firm default risk	Z_score	Proxied by Altman Z-score estimated for private companies.
Ability to provide collateral	Coll	Calculated by tangible assets over total assets
Change in sales	ΔSales	Measured by the change of natural logarithm of sales between *t* and *t-1*
Ownership concentration	Own	Measured by a scale coming from 1 (independent companies) to 4 (directly majority owned companies)
Year	Year	Measured by introducing different dummies for every year
Change in total amount of bank loans	L_t^d , L_t^s	Measured by the change in natural logarithm of total amount of bank loans between *t* and *t-1*

Table 1 defines the variables used in the paper. The data source is Aida database.

The model we consider is the following:

$$L_t^d = \alpha + \beta_1 Size_{t-1} + \beta_2 ST\_Fin_t + \beta_3 LT\_Fin_t + \beta_4 Cash_t + \beta_5 Sub\_f_t + \beta_6 Sub\_c_t + \beta_7 Int_{t-1} + \beta_8 Year_t + \varepsilon \quad (5)$$

$$L_t^s = \alpha + \gamma_1 Size_t + \gamma_2 Deb_{t-1} + \gamma_3 Roe_{t-1} + \gamma_4 Age_t + \gamma_5 Z\_score_{t-1} + \gamma_6 Coll_t + \gamma_7 \Delta Sales_t + \gamma_8 Own_t + \gamma_9 Year_t + \varepsilon \quad (6)$$

$$L_t = \min (L_t^d, L_t^s) \quad (3)$$

where L_t^d and L_t^s are the change in total amount of bank loans.

4. Sample

Following Ogawa and Suzuki (2000) and Atanasova and Wilson (2004), we use a panel data set to estimate the disequilibrium model of Italian SME corporate bank lending. Our sample consists of 142,066 Italian SMEs for the period 2007-2011.
Firm balance sheet data were extracted from the AIDA database. This database gives comprehensive information on Italian companies; it contains detailed accounts in compliance with the Fourth Directive (CEE) and information on: company financials, financial strength indicators, number of employees, local units, stock data (for listed companies), shareholders, ownership and management. The following selection criteria were imposed for inclusion in the sample: (i) being private Italian SMEs[1], (ii) having available data for at least one year in the period 2007-2011; (iii) not belonging to financial and public service sectors. Table 2 reports the distribution of observations over different years for our samples.

[1] According to the EU definition, Small and Medium Enterprises are defined as firms which employ fewer than 250 persons and whose annual turnover or annual balance sheet total does not exceed 43 million euro and 50 million euro respectively.

Table 2
Distribution of observations over years

Year	Number of firms	Number of firms - percentage	Number of firms (cumulative)	Number of firms - percentage (cumulative)
2006	20,221	14.23%	20,221	14.23%
2007	21,812	15.35%	42,033	29.59%
2008	22,256	15.67%	64,289	45.25%
2009	24,965	17.57%	89,254	62.83%
2010	25,647	18.05%	114,901	80.88%
2011	27,165	19.12%	142,066	100.00%
Total	142,066	100.00%	142,066	100.00%

Table 2 shows that the number of observations is well distributed among the period, with between 20,000 and 27,000 observations for each year. Looking at the distribution of observations across the industries (Table 3) "Wholesale" and "Construction" industry contribute most with over 30% of the total observations.

Table 3
Distribution of observations over industry

	2006	2007	2008	2009	2010	2011	Total
Agriculture	167	180	179	180	187	191	1,084
Mining	118	129	113	136	140	132	768
Manufacturing	946	1,004	1,010	1,164	1,241	1,308	6,673
Textiles and clothes	1,217	1,298	1,292	1,408	1,371	1,424	8,010
Wood and paper paste	2,328	2,494	2,477	2,797	2,804	2,974	15,874
Metallurgy	1,959	2,064	2,102	2,325	2,355	2,519	13,324
Electronics	2,030	2,155	2,181	2,461	2,450	2,596	13,873
Automotive	303	312	336	356	355	357	2,019
Forniture	396	425	418	448	432	436	2,555
Other manufacturing	358	377	373	423	441	450	2,422
Energy	459	517	544	652	718	816	3,706
Construction	2,376	2,643	2,691	2,971	3,116	3,329	17,126
Wholesale	4,251	4,511	4,625	5,254	5,332	5,532	29,505
Retail commerce	686	753	784	893	952	1,008	5,076
Transport	746	844	878	1,017	1,061	1,114	5,660
Service	213	253	252	276	270	305	1,569
Communication	153	183	186	197	196	217	1,132
Informatics	241	249	279	314	341	395	1,819
Advisory	551	622	685	741	836	882	4,317
Tourism	323	364	379	438	488	556	2,548
Education	20	21	24	29	34	39	167
Health	255	267	282	288	302	342	1,736
Entertainment	62	69	78	102	110	118	539
Other services	63	78	88	95	115	125	564
Total	20,221	21,812	22,256	24,965	25,647	27,165	142,066

The sample is in general representative of the Italian economy as a whole. The data refer only to Italy but give an insight into the whole Eurozone. Italian credit growth as well as many other quantitative aspects of the Italian loan market are, in fact, very similar to corresponding aspects in the whole area. For examples, the correlation between Italian and European series

of credit growth, bank interest rates, and the various European Central Bank (ECB) survey indices, is very high.
Table 4 reports some descriptive statistics for the variables used.

Table 4
Descriptive statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
Size	16.201	16.130	23.565	11.187	0.944	0.519	5.318
ST_Fin	-0.010	0.000	20.843	-254.662	1.183	-154.172	27098.670
LT_Fin	0.202	0.000	15224.100	-11536.510	72.191	86.118	27737.020
Cash	2.540	0.038	353833.500	-3.424	938.765	376.910	142062.000
Sub_f	0.025	0.000	0.972	-0.585	0.069	4.744	33.508
Sub_c	0.264	0.238	1.727	-0.407	0.166	0.863	3.748
Int	5.723	5.180	20.000	0.000	3.992	0.924	4.038
Deb	66.067	5.975	5754359.000	-0.438	15275.310	376.297	141752.200
Roe	8.598	4.940	148.590	-149.510	18.068	0.082	12.805
Z_score	1.623	1.505	13.006	-1.359	0.889	2.083	15.499
Coll	0.220	0.163	0.998	-0.042	0.204	1.134	3.877
ΔSales	-0.025	0.000	14.691	-13.102	0.526	-3.700	73.193
Own	3.044	4.000	4.000	1.000	1.122	-0.472	1.547

Table 4 shows descriptive statistics of the sample (142,064 observations).

Finally, Table 5 shows the correlations between the independent variables. The results appear to support the theory that every independent variable has its own informative value in explaining the dependent variable.

Table 5
Correlation matrix

	Size	ST_Fin	LT_Fin	Cash	Sub_f	Sub_c	Int	Deb	Roe	Z_score	Coll	ΔSales	Own
Size	1.000	-0.048	-0.002	-0.008	0.010	-0.374	-0.063	0.001	-0.095	-0.454	0.191	-0.219	0.044
ST_Fin	-0.048	1.000	0.000	0.000	0.000	-0.002	-0.002	0.000	0.002	0.011	-0.002	0.110	0.001
LT_Fin	-0.002	0.000	1.000	0.000	-0.001	0.006	0.003	0.000	0.005	0.001	-0.001	0.002	0.002
Cash	-0.008	0.000	0.000	1.000	-0.001	0.007	0.003	0.000	0.006	0.005	-0.002	0.001	0.002
Sub_f	0.010	0.000	-0.001	-0.001	1.000	-0.111	0.038	-0.001	-0.037	-0.086	0.052	-0.019	0.012
Sub_c	-0.374	-0.002	0.006	0.007	-0.111	1.000	0.057	-0.002	0.104	0.369	-0.358	0.139	-0.026
Int	-0.063	-0.002	0.003	0.003	0.038	0.057	1.000	0.002	-0.043	0.022	-0.015	-0.034	-0.005
Deb	0.001	0.000	0.000	0.000	-0.001	-0.002	0.002	1.000	-0.008	-0.004	0.006	0.000	-0.005
Roe	-0.095	0.002	0.005	0.006	-0.037	0.104	-0.043	-0.008	1.000	0.304	-0.167	-0.014	0.015
Z_score	-0.454	0.011	0.001	0.005	-0.086	0.369	0.022	-0.004	0.304	1.000	-0.334	-0.050	-0.023
Coll	0.191	-0.002	-0.001	-0.002	0.052	-0.358	-0.015	0.006	-0.167	-0.334	1.000	0.006	-0.044
ΔSales	-0.219	0.110	0.002	0.001	-0.019	0.139	-0.034	0.000	-0.014	-0.050	0.006	1.000	0.007
Own	0.044	0.001	0.002	0.002	0.012	-0.026	-0.005	-0.005	0.015	-0.023	-0.044	0.007	1.000

Table 5 shows the correlation matrix of the independent variables (142,064 observations).

5. Results

5.1 Estimation results

Results of the disequilibrium model for corporate bank lending are reported in Table 6, which takes into account the period 2007-2011.

Table 6
Demand and supply of credit

	Variables	Coefficient	Std. Error	Probability
L_t^d	Year 2010	-0.097225***	0.011773	0.0000
	Year 2009	-0.082274***	0.012581	0.0000
	const	1.494747***	0.094104	0.0000
	$Size_{t-1}$	-0.072159***	0.005473	0.0000
	ST_Fin_t	0.041329***	0.000827	0.0000
	LT_Fin_t	5.63E-05	0.000132	0.6708
	$Cash_t$	-4.07E-05***	2.45E-07	0.0000
	Sub_f_t	-0.289879***	0.046783	0.0000
	Sub_c_t	-0.209453***	0.026571	0.0000
	Int_{t-1}	-0.021883***	0.000932	0.0000
L_t^s	Year 2010	0.039390***	0.012377	0.0015
	Year 2008	-0.028496***	0.010305	0.0057
	const	-1.658395***	0.077526	0.0000
	$Size_t$	0.095094***	0.004504	0.0000
	Deb_{t-1}	-2.77E-06***	1.35E-08	0.0000
	Roe_{t-1}	0.000636	0.000560	0.2559
	Age_t	-0.073272***	0.018606	0.0001
	Z_score_{t-1}	0.150600***	0.006033	0.0000
	$Coll_t$	0.111532***	0.021554	0.0000
	$\Delta Sales_t$	0.434931***	0.003691	0.0000
	Own (if Roe<0) $_t$	-0.011074***	0.004284	0.0097
	demand residual σ_d	1.179687	0.002046	0.0000
	supply residual σ_s	1.42E-06	8.71E-09	0.0000
	Log likelihood	641858.5		
	Avg. log likelihood	5.267958		
	N. of observations	121942		
	Number of Coefs.	24		

Table 6 reports the disequilibrium model for the period 2007-2011 applied to Equations (3), (5) and (6), where the dependent variable is the change in natural logarithm of total amount of bank loans between t and t-1. The estimation was performed by means of the LLM (log-likelihood method) statistical package E-views 7.

As regards the demand equation, all economic independent variables are significant at 1% level, except for long term financing needs.
More specifically, the dependent variable is inversely related with firm size: this means that smaller firms requested more bank credit than the larger ones, as shown by Atanasova and Wilson (2004), Carbo-Valverde, Rodriguez Fernandez and Udell (2009) and Iyer, Lopes, Peydro and Schoar (2013). This suggests that SMEs are probably the most prone to credit rationing, which is consistent with previous literature (Fazzari et al., 1988; Calomiris and Hubbard, 1990; Gertler and Gilchrist, 1994). Second, companies registering the higher increase in working capital in the year *t* compared to year *t-1* exhibit the most demand for short-term credit. This confirms the evidence found by Kremp and Sevestre (2012). Third, the

demand for loans increases if a firm has fewer internal available sources. This evidence supports the "*pecking order theory*" (Myers and Majluf, 1984; Fama and French, 2002), according to which companies prefer internal available resources to bank credit, as suggested by Atanasova and Wilson (2004), Carbo-Valverde, Rodriguez Fernandez and Udell (2009) and Kremp and Sevestre (2012). As predicted, SMEs with more available substitutes for bank finance (i.e. non-bank financial debts and commercial debts) show a lower demand for loans.
Moreover, the coefficient of the cost of bank debt is significantly negative. This means that a higher interest rate applied by financial companies reduces the desire for bank credit, as shown by Carbo-Valverde, Rodriguez Fernandez and Udell (2009) and Kremp and Sevestre (2012). Examining the time dummies, the results show that the demand for bank credit was lower in 2009 and 2010, other year dummies (2007, 2008 and 2011) being not significant. They do not therefore appear in Table 6.
As regards the supply equation, the results are consistent with our expectations, as all explanatory variables, with one exception, are found significant at 1% or 5% level. The only insignificant explanatory variable in our model is the index of firm profitability (Roe_{t-1}). A possible explanation is that the firm risk (Z_score_{t-1}) and the increase in sales (ΔSales) are sufficient for banks to have information about firm profitability.
Firm size shows a significant positive effect on the amount of bank credit supplied to the company. This means that in the credit rationing process, banks reduced lending more to smaller companies than to larger firms, as predicted by Hypothesis 2. These results are consistent with the evidence found by Carbo-Valverde, Rodriguez Fernandez and Udell (2009). As predicted, credit supply is inversely related to previous firm financial debt, because banks are reluctant to allocate new credit to firms which are already strongly indebted, as suggested by Kremp and Sevestre (2012). Contrary to our hypothesis (Hypothesis 3), the negative coefficient for the age of the firm indicates that younger companies are offered more bank credit. This evidence, differing from Kremp and Sevestre (2012), can be explained by considering that firms younger than 5 years represent only 5% of the total sample.
The Altman Z-score shows a positive relationship with credit supply. This means that, as predicted, banks prefer to offer credit to firms characterized by low default risk degree, for which the repayment of the loans is more certain. This confirm that the "*flight to quality effect*", which Albertazzi and Domenico (2010) identify in Italy in the period 2008-2009, persists in the following years 2009, 2010 and 2011. The ability to provide collateral, which in the literature shows an ambiguous link with credit supply, is found to exert a positive effect on a company ability to borrow loans from banks. In other words, banks prefer to allocate new credit to firms which can offer collateral, because in the case of default, financial companies can sell the collateral and recover the loans totally or partially. As predicted, the amount of tangible assets available to offer as collateral seems indeed to be considered a risk mitigant by banks, as shown by Carbo-Valverde, Rodriguez Fernandez and Udell (2009) and Kremp and Sevestre (2012). The coefficient of the change in sales is significantly positive, thus suggesting that firms with the bigger decreases in sales are more financially constrained.
In the case of low firm profitability, ownership structure shows a negative relationship with the dependent variable. This means that banks consider a strong ownership concentration a negative element in deciding for lending. This result is consistent with Hypothesis 4. Private firms where the ownership is concentrated show indeed a high cost of capital and are often characterized by the presence of a large shareholder trying to deprive small owners of their part of residual income. On the contrary, in widespread ownership firms, shareholders exert control over one another and, moreover, all of them can offer personal collateral to banks.
Examining the time dummies, the results show that the supply for bank credit was somewhat lower in 2008 and higher in 2010, other year dummies (2007, 2009 and 2011) being not significant. They are therefore not shown in Table 6.

By means of our disequilibrium model we calculate the amount of bank credit requested by Italian SMEs and supplied by banks. We estimate credit rationing as the difference between the demand for bank credit of the firm *i* in the year *t* and the supply of loans offered in the same period, where demand exceeds supply. Table 7 shows the percentage of firms credit rationed in the period 2007-2011.

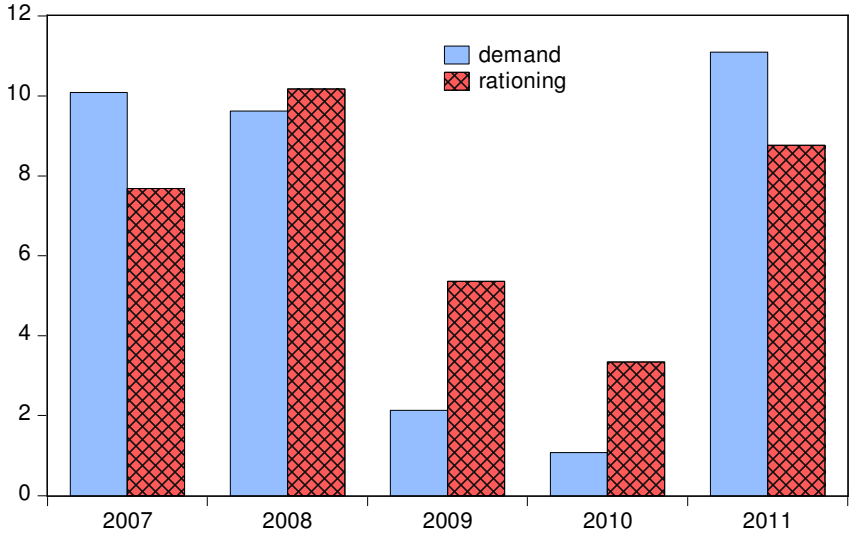
Table 7
Credit rationing in the period 2007-2011

	SMEs credit rationed (percentage)	SMEs credit rationed over 5% (percentage)	SMEs credit rationed over 10% (percentage)
2007	47.5%	36.3%	25.5%
2008	53.9%	42.9%	32.0%
2009	33.8%	23.4%	16.0%
2010	16.3%	11.2%	7.7%
2011	40.1%	39.2%	27.6%

Table 7 reports credit rationing estimations for the period 2007-2011. The Table shows the percentage of all credit rationed SMEs (column 1), the percentage of SMEs credit rationed over 5% (column 2) and the percentage of SMEs credit rationed over 10% (column 3).

As predicted, the results suggest that Italian SMEs have been credit rationed during the crisis, especially in the years 2007, 2008 and 2011. During the crisis, credit rationing was caused by both demand-side and supply-side factors, as suggested by Hypothesis 1. More specifically, in the period 2009-2010, demand was very low. But in the years 2007, 2008 and 2011, reduction in bank lending was mainly due to supply effect, as shown in Figure 1, which presents the relevance of mean demand and rationing in determining the credit growth of individual firms.

Figure 1
Relevance of mean demand and rationing in determining the credit growth of individual firms



Since our individual demand and supply of credit are only estimated values, a small positive difference between demand and supply might be simply consequence of the approximations and not the effect of a true rationing phenomenon. For this reason we calculated not only the percentage of firms which demand for credit was higher than supply, but also the number of cases where the desired growth of the loans is 5% and 10% higher than that offered by banks.

Although the percentages are smaller, the overall picture is the same: SME rationing was particularly high in 2008 and 2011. It is also apparent that rationing is higher in years of financial or real sector crisis.
Another important result of our estimations is that individual rationing is a persistent phenomenon: firms rationed in *t* also tend to be rationed in *t+1* and *vice versa*. After defining the variable "*rationed*" as a dummy variable assuming 1 if the credit demand of a firm is higher than its correspondent supply, and 0 otherwise, we apply a probit estimation (Table 8). This estimation shows that the lagged dependent variable ("*rationed*" in t-1) is found positive and strongly significant.

Table 8
Probit analysis applied to individual firm rationing

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.071273	0.035949	-1.982635	0.0474
Year =2008	0.071301	0.036957	1.929324	0.0537
Year =2009	-0.338355	0.036564	-9.253772	0.0000
Year =2010	-0.476038	0.036369	-13.08913	0.0000
Year =2011	0.439951	0.036902	11.92232	0.0000
Rationed $_{t-1}$	1.160883	0.010738	108.1116	0.0000

McFadden R-squared	0.165624	Mean dependent var	0.714474
S.D. dependent var	0.451667	S.E. of regression	0.404295
Akaike info criterion	0.998223	Sum squared resid	13286.55
Schwarz criterion	0.998910	Log likelihood	-40567.78
Hannan-Quinn criter.	0.998433	Deviance	81135.55
Restr. deviance	97241.04	Restr. log likelihood	-48620.52
LR statistic	16105.49	Avg. log likelihood	-0.499038
Prob(LR statistic)	0.000000		

Obs with Dep=0	23211
Obs with Dep=1	58081

Table 8 reports the probit model for the period 2007-2011. The estimation was performed by means of the ML - Binary Probit (Quadratic hill climbing). The covariance matrix is computed using second derivatives.

5.2 Robustness checks

The results proved extremely robust along several dimensions.
A first robustness exercise is related to the empirical methodology. Since the disequilibrium model determines both the demand for credit and the corresponding bank supply to individual firms determined on the basis of their balance sheets, it is important to compare our results with those obtained by other methodologies. In particular, a useful comparison can be made between our results and those obtained by surveys, i.e. the Italian section in the ECB's Bank Lending Survey (BLS) as well the survey on the access to finance of SMEs in the euro area (SAFE). These surveys contain, among other data, information about the aggregate demand for credit and SME rationing broken down by country.

Information about aggregate credit demand from the quarterly BLS, corresponds to Question 4 of the survey ("*Over the past three months, how has the demand for loans or credit lines to enterprises changed at your bank, apart from normal seasonal fluctuations?*"). The answers, collected by the Bank of Italy, are used to construct both percentages and "diffusion" indices, whose historical behaviour is however very similar.

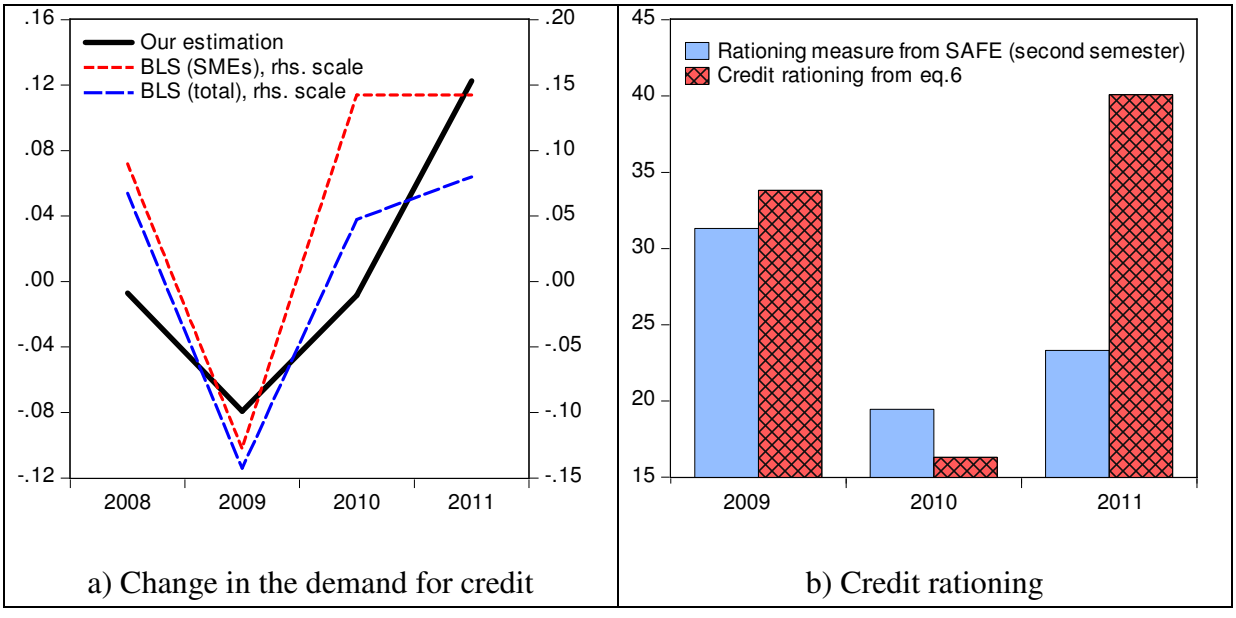
Data on SME credit rationing can be found in SAFE. This survey has been conducted twice a year since 1999 on a sample of randomly selected companies stratified by firm size class (based on the number of employees), economic activity and country. SAFE contains firm-level information related to company structural characteristics (size, ownership, age, sector, turnover) and firms' assessment regarding their financing needs and access to finance. We measure the existence of financing obstacles through the answers to the following question (Question 7B_A of the questionnaire): "*If you applied and tried to negotiate for this type of financing (i.e. bank loan) over the past six months, did you receive all the financing you requested, or only part of the financing you requested, or only at unacceptable costs or terms and conditions so you did not take it, or have you not received anything at all?*" Firms can choose among a set of possible answers: (1) applied and received everything; (2) applied and got part of it; (3) applied but costs too high; (4) applied but rejected; (5) did not apply because of fear of being rejected; (6) did not apply because of sufficient internal funds; (7) did not apply for other reasons. Firms that choose answers (2), (3) and (4) from the options are presumed to face obstacles to financing.

Although we used an econometric analysis which is very different from BLS and SAFE, our results should be qualitatively consistent given that the phenomena under analysis are the same. They results cannot be mutually inconsistent.

Figures 2 a) and b) report the comparison between our estimations and the survey data. Survey data relative to demand have been aggregated in order to get the same annual frequency as the balance sheets we used, and we use the mean values of our single firm data. The demand for loans shown in Figure 2 a) corresponds to the mean value of the various credit demands, while credit rationing is measured as the percentage of firms for which demand is higher than supply.

Figure 2

A comparison between our results and the ECB and Bank of Italy surveys



a) Change in the demand for credit

b) Credit rationing

The behaviours of the variables from the two different sources do not appear to conflict. Our estimations therefore seems to be credible, from this point of view at least. The econometric result therefore appears to supply useful information about the balance sheet items which determine the demand from, as well the supply of credit to, Italian SMEs.

A further robustness exercise is related to the choice of variables. More specifically, variations of Equations (5) and (6) were estimated in order to assess the robustness of the results.

First, in Equation (5), the following two variables were tested to account for financing needs: (i) sales to account (Atanasova and Wilson, 2004; Carbo-Valverde et al., 2009) over total assets in place of the increase in working capital over total assets, and (ii) the amount of investment over value added (De Mitri et al., 2010) in place of the amount of investment over total assets. We also replaced in Equation (5) non-bank financial debt over total assets and commercial debt over total assets with non-bank financial debt over total financial debts and commercial debt over total sales, respectively.

Our results confirm previous findings. More specifically, credit demand is positively related to short-term financial needs and negatively related to firm size, internal available resources, substitute for bank finance and cost of bank debt.

Second, in Equation (6), the following two variables were tested to account for firm indebtness and company profitability: (i) financial debt to total assets in place of financial debt to net cash flow, and (ii) the return on assets in place of the return on equity.

Once again, this result seems to substantially confirm previous findings. More specifically, credit supply is positively related to firm size, company default risk degree, ability to provide collateral and change in sales, and negatively related to level of indebtness, firm age and ownership concentration.

We also substitute in Equation (5) and (6) the dependent variable (change in natural logarithm of total amount of bank loans between *t* and *t-1*) with the ratio between the increase in credit loans and total assets in t-1 (De Mitri et al., 2010). Our results confirm previous evidence, as shown in Table 9.

Table 9
Demand and supply of credit with alternative dependent variable

	Variables	Coefficient	Probability
L_t^d	Year 2010	0.059950***	0.0000
	Year 2009	-0.008920***	0.0000
	const	1.501249***	0.0000
	$Size_{t-1}$	-0.074498***	0.0000
	ST_Fin_t	0.000114	0.8292
	LT_Fin_t	-1.49E-06	0.9794
	$Cash_t$	-3.89E-06***	0.0000
	Sub_f_t	-0.253729***	0.0000
	Sub_c_t	-0.397326***	0.0000
	Int_{t-1}	0.001482***	0.0000
L_t^s	Year 2010	-0.001977**	0.0336
	Year 2008	0.004258***	0.0000
	const	-0.259063***	0.0000
	$Size_t$	0.016741***	0.0000
	Deb_{t-1}	-1.60E-07***	0.0000
	Roe_{t-1}	-7.12E-06	0.8238
	Age_t	-0.011715***	0.0000
	Z_score_{t-1}	0.014849***	0.0000
	$Coll_t$	0.007329***	0.0000
	$\Delta Sales_t$	0.060113***	0.0000
	Own (if Roe<0) $_t$	-0.002856***	0.0000

	demand residual σ_d supply residual σ_s	0.021396 2.45E-05	0.0000 0.0000
	Log likelihood	641858.5	
	Avg. log likelihood	5.267958	
	N. of observations	121942	
	Number of Coefs.	24	

Table 9 reports the disequilibrium model for the period 2007-2011 applied to Equations (3), (5) and (6), where the dependent variable is the ratio between the increase in credit loans and total assets in t-1. The estimation was performed by means of the LLM (log-likelihood method) statistical package E-views 7.

Finally, we estimate the disequilibrium model by adding industry dummies to both demand and supply functions. Once again, our results seem to substantially confirm previous findings.

6. Conclusions

On the basis of a large panel data set of private Italian SMEs, this paper estimates a disequilibrium model of demand and supply of credit in the period 2007-2011.The novelty of this study is that it investigates the Italian credit market during the recent crisis by applying a disequilibrium model. This model allows us to separate financially constrained and unconstrained firms on the basis of demand factors.

The results of our study show that, over the period 2007-2011, private Italian SMEs have been credit rationed, especially in the years 2007, 2008 and 2011. This evidence is consistent with surveys conducted by the Bank of Italy and the European Central Bank.

On the demand side, firms which requested more bank credit are smaller companies, showing the higher increase in working capital, fewer internal available sources and fewer substitutes for bank finance. On the other hand, higher interest rates applied by financial companies lowered the requirement for bank credit.

On the supply side, banks reduced lending more to smaller and highly indebted firms which presented a high degree of default risk. Banks preferred to allocate new credit to Italian SMEs which could offer collateral and showed bigger increases in sales. Surprisingly, older firms have been more financially constrained than the younger ones. Our results also show that banks consider a strong ownership concentration a negative element in deciding for lending. To our knowledge, this paper is the first to take into account the relationship between concentrated ownership and credit rationing.

The work could be further refined by investigating the reactions of firms to credit rationing and disaggregating short-term and long-term credit rationing.

Appendix

In estimating of SME demand and supply of credit in Italy we employed the same log-likelihood method (LLM) used by Kremp and Sevestre (2012), even if our specification is somewhat simpler because we did not consider firms with zero-bank loans. Since LLM estimators may present convergence problems, we supplied the EViews 7 routine with realistic starting values derived from a non-linear LS estimator. The condition for discriminating between demand and supply of credit are the following:

$$L_t^d = \beta_1 x_{1t} + \varepsilon_{1t} \quad \text{(a1)}$$

$$L_t^s = \beta_2 x_{2t} + \varepsilon_{2t} \quad \text{(a2)}$$

$$L_t = \min (L_t^d, L_t^s) \quad \text{(a3)}$$

The system (a1)-(a2)-(a3) can be easily simplified in:

$$L_t = L_t^d \, [L_t^d \leq L_t^s] + L_t^s \, [L_t^d > L_t^s] \quad \text{(a4)}$$

or

$$L_t = L_t^d + (L_t^s - L_t^d)[L_t^d > L_t^s], \quad \text{(a5)}$$

where the logical symbol [xRy] correspond to 1 if xRy is true, 0 otherwise. Equation (a5) can so be explicited as:

$$L_t = (\beta_1 x_{1t} + \varepsilon_{1t}) + (\beta_2 x_{2t} + \varepsilon_{2t} - \beta_1 x_{1t} - \varepsilon_{1t}) \, [\beta_1 x_{1t} - \beta_2 x_{2t} > \varepsilon_{2t} - \varepsilon_{2t}] \quad \text{(a6)}$$

$$L_t = \beta_1 x_{1t} + (\beta_2 x_{2t} - \beta_1 x_{1t}) \, [\beta_1 x_{1t} - \beta_2 x_{2t} > \varepsilon_{2t} - \varepsilon_{2t}] + \varepsilon_{1t} + (\varepsilon_{2t} - \varepsilon_{1t}) \, [\beta_1 x_{1t} - \beta_2 x_{2t} > \varepsilon_{2t} - \varepsilon_{2t}] \quad \text{(a7)}$$

that we estimated under the approximated form:

$$L_t = \beta_1 x_{1t} + (\beta_2 x_{2t} - \beta_1 x_{1t}) \, [\beta_1 x_{1t} - \beta_2 x_{2t}] + \textit{residuals} \quad \text{(a8)}$$

in order to have the starting coefficients, even if biased, to use as starting values for the EViews maximum likelihood iterations.
Moreover, define:

$$\varepsilon_D = L_t - \beta_1 x_{1t} \text{ if } L_t \text{ is a demand} \quad \text{(a9)}$$

$$\varepsilon_S = L_t - \beta_2 x_{1t} \text{ if } L_t \text{ is a supply} \quad \text{(a10)}$$

$$\sigma_D = \sigma(\varepsilon_D) \text{ and } \sigma_S = \sigma(\varepsilon_S) , \quad \text{(a11)}$$

$$\rho = \text{correlation between } \varepsilon_D \text{ and } \varepsilon_S \quad \text{(a12)}$$

$$\varphi(.) = \text{the normal N(0,1) density function} \quad \text{(a13)}$$

$$\Phi(.) = \text{the cumulative normal N(0,1) density function} \quad \text{(a14)}$$

The components of εD independent from εS (corresponding to the residuals of the regression of εD on εS) are given by:

$$\varepsilon D' = \varepsilon D - (\rho \sigma D / \sigma S) \varepsilon S. \quad \text{(a15)}$$

Similarly,

$$\varepsilon S' = \varepsilon S - (\rho \sigma S / \sigma D) \quad \text{(a16)}$$

are the components of εS independent from εD. The standard deviations of εD' and εS' are

$$\sigma D' = \sigma D (1 - \rho 2) 1/2 \quad \text{(a17)}$$

and

$$\sigma S' = \sigma S(1-\rho 2)1/2 \qquad (a18)$$

respectively. The basic idea is that the probability for the actual L_t to be a supply is higher the lower $\varepsilon D'$: if L_t is much lower than its corresponding estimated demand, the possibility of a rationing is high. In terms of probability,

$$\text{Prob(Lt is a supply)} = [1 - \Phi(\varepsilon D'/\sigma D')]. \qquad (a19)$$

On the other hand, the lower are the actual loans compared to their estimated supply and the more likely that the demand is low and there is no rationing (that is, L_t is a demand):

$$\text{Prob}(L_t \text{ is a demand}) = [1 - \Phi(\varepsilon S'/\sigma S')]. \qquad (a20)$$

The contribution to the likelihood of an observation t is therefore:

$$[\varphi(\varepsilon D'/\sigma D')/\sigma D'] [1 - \Phi(\varepsilon S'/\sigma S')] + [\varphi(\varepsilon S'/\sigma S')/\sigma S'] [1 - \Phi(\varepsilon D'/\sigma D')]. \qquad (a21)$$

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