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Volatility and financial intermediation

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Abstract

We consider an economy where risk neutral banks provide intermediation services and risk neutral producers demand credit to finance their working capital needs. Our model blends costly state verification with imperfect enforcement power. We show that a weak legal system combined with high information verification costs leads to large, first-order effects of volatility on production, employment and welfare. A calibration illustrates that a 1% increase in the coefficient of variation of productivity shocks would reduce welfare by more than 1%. We suggest that legal and information problems explains why volatility has profound effects on emerging market economies.

JEL classification: F32; F34; E44

Keywords: Costly financial intermediation; Volatility; Working capital

1. Introduction

Following the Tequila period, its after-effects in Latin America and more recent events in South East Asia, the effect of volatility on emerging market economies has become an important topic of research (see Sachs et al., 1996; Edwards and Vegh, 1997; and Agenor and Aizenman, 1998). In many of these papers, the domestic financial intermediation process is advanced as one of the most important transmission mechanisms for volatility effects. At the same time there has been continued interest in issues related to imperfect information and rationing in credit markets

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(see the seminal article by Stiglitz and Weiss (1981), the review by Jaffee and Stiglitz (1990) and the many references therein). The themes in this literature include imperfect information and imperfect legal enforcement powers and (hence) high lending spreads and/or credit rationing.

What appears to be lacking in the literature is a model which combines elements of the microeconomic models of credit markets which gives rise to costly financial intermediation combined with the effects of volatility on production in an economy where credit is an input. To some extent, Edwards and Vegh (1997) is the closest model to attempt to close this circle and these authors generate interesting results regarding the effects of external shocks on economic performance. However, in their model financial intermediation is costly because of an exogenously imposed non-remunerated reserve requirement on banks rather than any more fundamental problem in the credit market and, although shocks are analyzed, the model does not incorporate uncertainty explicitly. We feel that to capture the effects of volatility on macroeconomic performance, uncertainty should be modeled directly and we prefer to model banking costs as the result of information and enforcement imperfections.

To motivate the following theoretical analysis, we first present some statistical information regarding Argentina. Argentina is a country which suffered more than most from the fall-out of the Mexican devaluation at the end of 1994 and the increase in perceived risk as international investors considered that the current economic program, often referred to as the Convertibility Plan, was at risk. As illustrated in Fig. 1, this economic program had resulted in strong GDP growth since its implemen-

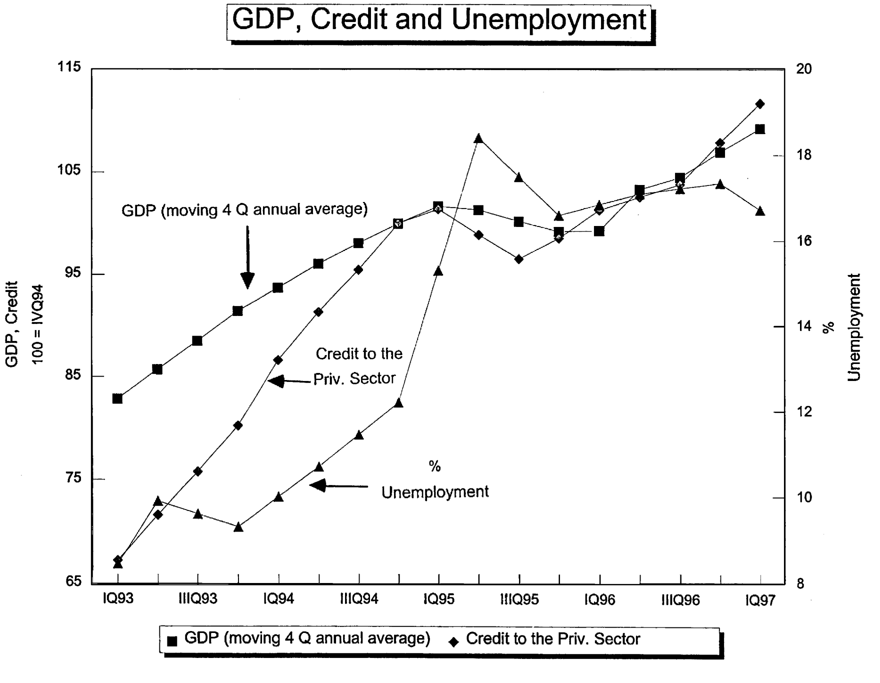

Fig. 1. GDP, credit and unemployment, Argentina 1993–1996.

tation in 1991 and a strong growth in credit to the non-financial private sector. However, in 1995 the nominal credit to the non-financial private sector fell by 3.4% (from the fourth quarter of 1994 to the second quarter of 1995, when the level of credit was at a minimum). Over the same year, nominal GDP fell by some 4.3% (third quarter 1995 over third quarter 1994) and unemployment rose from 12.2% in November 1994 to a peak of 18.4% in May 1995. The fall in GDP and the rise in unemployment was largely attributed to the credit-crunch in the economy following the increase in perceived volatility.

A more detailed analysis of the credit market reveals a number of further interesting features. Argentina provides an example of a country with high average lending spreads but also a very high dispersion of interest rates. Table 1 gives statistics on average lending rates plus the standard deviation of rates charged across banks in the financial system broken down by different types of credit, and Fig. 2 illustrates the distributions of these interest rates across banks in the financial system for different loan categories for 1995–1996.

Four points are worth noting with respect to these statistics. First, lending interest rates remain high (the average lending rate in the system in 1996 was about 18%) especially bearing in mind that inflation in Argentina was of the order of 1% for the same year. Second, average rates vary depending on the type of credit with very high rates found for overdraft facilities and personal credits which have no guarantees and significantly lower rates found for mortgages, other collateralized loans and also for lending on bills discounted—largely for firms' working capital needs. Third, the figure illustrates that the dispersion of interest rates across banks remains very high. Fourth, the standard deviation depends very much on the type of loan with typically low standard deviations found for those loans with guarantees (mortgages and other secured credits) and for loans to companies for working capital (discounted bills) and high standard deviations for non-secured loans, such as overdraft facilities and personal credit.

At first sight, these stylized facts do not accord with the simplest theoretical models of credit rationing. Indeed, the traditional quantity credit-rationing story implies that observed interest rates might be lower than expected and that, given banks' incapacity to discriminate, the dispersion of observed rates might also be low. Naturally, such highly stylized models are designed to convey the strong message that information asymmetries may result in market imperfections and do not, by design, attempt to reflect the complexities of actual financial contracting within a varied market-place.

In this paper we present a model which we believe is sufficiently rich to explain many of these stylized facts. The model also retains the central message of simple credit rationing stories in that there may still be a backward bending supply curve for credit. The added richness stems from assuming that individuals are subject to an uncertain 'productivity shock', that repayment is an active decision of the debtor who may chose to default depending on potential legal penalties and that there is imperfect information in that it is costly for banks to verify customer income in default states. Each of these items (uncertainty, legal penalties and the state verifi-

Table 1
Lending rates by groups of banks, second quarter, 1996

	Overdrafts		Bills discounted		Mortgages		Pledges		Personal loans	
	Lending rate	Standard deviation	Lending rate	Standard deviation	Lending rate	Standard deviation	Lending rate	Standard deviation	Lending rate	Standard deviation
Private banks	30.0	12.1	11.7	7.7	13.7	3.5	17.0	3.1	36.3	10.5
National	32.3	11.3	13.5	6.1	13.2	3.9	17.1	2.9	35.0	12.1
Capital	29.7	9.4	11.7	3.3	12.2	3.5	16.1	2.3	33.5	11.8
Provincial	38.2	12.7	22.1	8.4	17.5	2.7	19.6	2.9	39.8	11.7
Foreign	24.9	12.5	9.9	8.7	14.5	1.7	16.7	3.5	38.5	6.6
Public banks	37.4	4.7	15.7	3.3	13.4	1.9	15.4	2.8	25.5	4.4
National	39.3	3.2	14.3	2.4	13.3	1.8	15.3	2.7	26.9	1.1
Provincial	34.8	5.2	19.0	2.5	15.5	2.1	16.3	3.6	24.5	5.5
Financial system	31.4	11.5	12.4	7.6	13.5	3.0	16.1	2.8	34.2	10.9

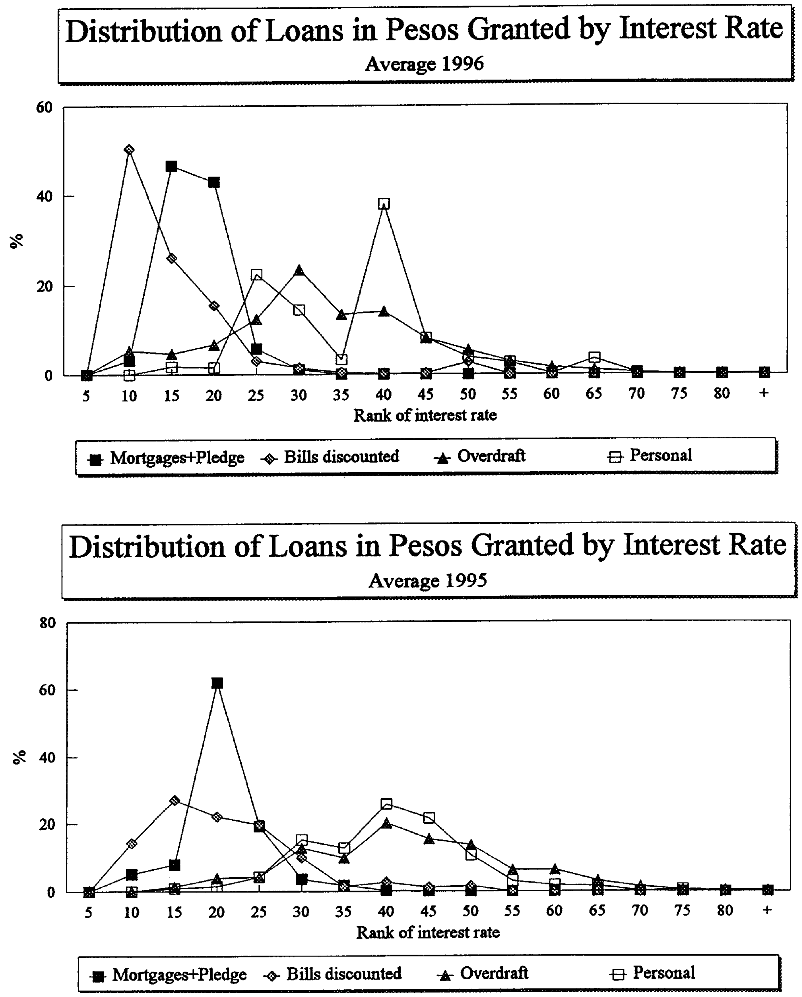

Fig. 2. The distribution of interest rates, 1995. Source: Central Bank, Argentina.

cation cost) could potentially vary across individuals and hence may explain the tremendous cross-sectional variation in the data.

Our model is not only capable of explaining this cross-sectional variation of interest rates, but also has strong implications for the combined effect of volatility and imperfect information on the supply of credit and (hence) on employment and output. In particular, we suggest that the effect of an increase in volatility may be multiplied by the presence of imperfect information causing much more significant drops in employment and output than might otherwise be expected. We show that a weaker legal system and more costly verification of information increases the welfare cost of volatility. The combination of these factors implies that volatility induces large, first order welfare and employment costs in countries characterized by costly intermediation. Our calibration illustrates that the semi-elasticity of welfare with respect to productivity shocks' coefficient of variation is below -1 for reasonable parameter values (i.e. a 1% increase in the coefficient of variation of productivity shocks would reduce welfare by more than 1%).

We suggest that the interaction of increased uncertainty, poor legal enforcement capabilities and imperfect information may then account for the severity of the effect of volatility on emerging market economies including Argentina. Moreover, our model predicts an increase in both average interest rates and in the dispersion of lending interest rates would follow a rise in uncertainty and as we have seen in the analysis above, both phenomena occurred in Argentina in 1995.

Our approach is then a blend of the state verification approach (due to Townsend (1979)) and the 'willingness to pay' models often associated with sovereign lending (Eaton et al. (1986) provides an early review). The idea is that banks have poor information with respect to client incomes (the return on projects undertaken by borrowers) and that borrowers decide whether to repay or not depending on the benefit of so doing and the penalties associated with default. Imperfect information is captured in the assumption that in default states, banks must pay a verification cost to capture at least a part of the borrower's income. However, banks do have some idea of the verification costs which may vary across clients and here we have in mind in particular the quality of the information on bank customers (balance sheets, income projections, etc.). We also investigate the case where banks cannot discriminate between clients at all and calculate the welfare consequences of the situation where banks must offer homogenous loan contracts. Volatility is captured by the uncertainty associated with the return on customers' projects and for combinations of high uncertainty and high costs for state verification, interest rates may be very high or indeed credit may not be offered at all. We also consider the use of collateral in the loan contract. Collateral turns out to be an important feature which can serve to both reduce the lending interest and increase the supply of credit. Furthermore, we find that collateral reduces the dispersion of interest rates as found in accord with the empirical evidence cited above.

The paper is organized as follows. In Section 2 we present the basic model and Section 3 describes a set of simulation results. Section 4 considers the case of endogenous output and employment and considers the consequences of increased volatility on economic performance. The results of the paper suggest certain policy conclusions which are discussed in Section 5. Section 6 concludes.

2. The model

We consider an economy where risk neutral banks provide intermediation services to risk natural producers. Agents demand credit to finance their working capital. Producers who lack access to the equity market rely on bank credit to finance the cost of variable inputs, due to be paid prior to production. Our model blends the costly state verification approach (Townsend, 1979) and the limited enforceability of contacts (used frequently in the external debt literature, as in Bulow and Rogoff, 1989). The project's future productivity is random. The realized productivity shock is revealed to banks, only at a cost. Producer's default on the bank's loan implies that the creditor would 'seize' any collateral set as part of the loan contract, plus a fraction κ of the project's value. Seizing involves two types of costs. First, verifying the net worth of the project is costly; second, enforcing repayment may require costly intervention of the legal system.

We assume a large number of domestic producers using an identical production function, subject to an i.i.d. productivity shock. The future output of agent i is given by

$$y_i = [M_i]^{\beta}(1 + \varepsilon_i); \quad 0 < \beta < 1, \quad |\varepsilon_i| \leq \mathrm{E} < 1 \tag{1}$$

where M denotes the variable input (raw material, labor, etc.), and ε_i is the realized idiosyncratic productivity shock. The contractual interest rate on the working capital of agent i, committing a collateral L_i, is $r_{L,i}$. We assume that producers must finance the variable input costs prior to the sale of output, and that they cannot issue claims on their capital stock. Consequently, producer i's variable costs are $(1 + r_{L,i})p_m M_i$, where p_m is the relative price of the variable input. The producer will default if the resultant debt service $(\kappa[M_i]^{\beta}(1 + \varepsilon_i) + L_i)$ is below the contractual repayment

$$\kappa[M_i]^{\beta}(1 + \varepsilon_i) + L_i < (1 + r_{L,i})p_m M_i \tag{2}$$

We denote by ε_i^* the highest productivity shock leading to default

$$\kappa[M_i]^{\beta}(1 + \varepsilon_i^*) + L_i = (1 + r_{L,i})p_m M_i. \tag{3}$$

If default never occurs, ε_i^* is set at the lower end of the support ($\varepsilon_i^* = -\mathrm{E}$). In case of default, the bank's net revenue is the producer's repayment minus the state verification and contract enforcement cost, C_i,[1]

$$\kappa[M_i]^{\beta}(1 + \varepsilon_i) + L_i - C_i. \tag{4}$$

We assume that banks have access to elastic supply of funds, at a real cost of r_0.[2] Banks are risk neutral and competitive. Each is serving a large enough pool of borrowers so as to diversify away the bank's exposure to the idiosyncratic risk, ε_i. The contractual interest rate is determined by the expected break-even condition:

$$(1 + r_0)M_i p_m = \int_{\varepsilon_i^*}^{\mathrm{E}} [(1 + r_{L,i})p_m M_i] f(\varepsilon) d\varepsilon + \int_{-\mathrm{E}}^{\varepsilon_i^*} [\kappa[M_i]^{\beta}(1 + \varepsilon) + L_i \tag{5}$$

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[1] The cost C is a lump sum, paid by banks to identify the productivity shock ε_i, and to enforce the proper payment. The analysis is more involved if some costs are paid after obtaining the information about ε_i. In these circumstances, banks will refrain from forcing debt repayment when the realized productivity is below an 'enforcement threshold.' For simplicity of exposition we refrain from modeling this possibility. We ignore also all other real costs associated with financial intermediation. Adding these consideration would not modify the key insight of our analysis.

[2] This credit may be supplied by foreign banks, as was modeled in a different context by Agenor and Aizenman (1998). The assumption that the supply of funds is elastic rules out the possibility of credit rationing due to supply shortage, a possibility modeled by Williamson (1986).

$$-C_i]f(\varepsilon)d\varepsilon$$

where $f(\varepsilon)$ is the density function. For future reference, it is useful to rewrite this condition as

$$(1+r_0)M_ip_m = (1+r_{L,i})p_mM_i - \int_{-\mathrm{E}}^{\varepsilon_i^*}[(1+r_{L,i})p_mM_i - \{\kappa[M_i]^\beta(1+\varepsilon) + L_i\} + C_i]f(\varepsilon)d\varepsilon. \tag{5'}$$

Substituting (3) into (5'), we obtain that the interest rate spread is determined by

$$r_{L,i}-r_0 = \frac{\int_{-\mathrm{E}}^{\varepsilon_i^*}[\kappa[M_i]^\beta(\varepsilon_i^*-\varepsilon)]f(\varepsilon)d\varepsilon}{p_mM_i} + \frac{C_i\int_{-\mathrm{E}}^{\varepsilon_i^*}f(\varepsilon)d\varepsilon}{p_mM_i}. \tag{6}$$

The contractual interest rate is determined by a 'mark up' rule, exceeding the bank's cost of funds by the sum of two terms. The first term is the expected revenue lost due to partial default in bad states of nature. The second term measures the expected state verification and contract enforcement costs. Note that a higher collateral increases the costs of default, reducing thereby the frequency of defaults (as seen from the drop of ε_i^*, see (3)). Consequently, higher collateral reduces the financial spread.The producer's expected net income equals

$$[M_i]^\beta - \int_{\varepsilon_i^*}^{\mathrm{E}}[(1+r_{L,i})p_mM_i]f(\varepsilon)d\varepsilon - \int_{-\mathrm{E}}^{\varepsilon_i^*}[\kappa[M_i]^\beta(1+\varepsilon) + L_i]f(\varepsilon)d\varepsilon. \tag{7}$$

Applying (5), we can simplify (7) to

$$[M_i]^\beta - (1+r_0)p_mM_i - C_i\int_{-\mathrm{E}}^{\varepsilon_i^*}f(\varepsilon)d\varepsilon. \tag{8}$$

The optimal employment of the variable input is found by maximizing (8).

If shocks follow a uniform distribution, $-\mathrm{E}\le\varepsilon\le\mathrm{E}$, the spread (6) is characterized by a quadratic equation,

$$r_{L,i}-r_0 = \mathrm{E}\frac{\kappa[M_i]^\beta}{p_mM_i}(\Phi_i)^2 + \frac{C_i}{p_mM_i}\Phi_i, \text{ where } \Phi_i = \frac{\mathrm{E}+\varepsilon_i^*}{2\mathrm{E}}. \tag{6'}$$

The term $\Phi_i = \frac{\mathrm{E}+\varepsilon_i^*}{2\mathrm{E}}$ is the probability of default. The second term of (6') is illustrative of how producers pay for the information asymmetry through the banks' mark-up rule given our assumption of a competitive banking sector. Combining equations (3), (6') and (8) one can infer that, for an internal solution where credit is supplied and where the probability of default is positive, the contractual interest rate in the partial default range is[3]

[3] To infer the relevant signs we solve explicitly ε_i^* using (3), and substitute it in (6').

$$r_{L,i} = r(\overset{+}{C}_i; \overset{-}{L}_i; \overset{-}{\kappa}; \overset{+}{\mathrm{E}}) \quad (9)$$

where the signs of partial effects are above the corresponding variables.

To gain further insight, we review in the next section the case where shocks follow a uniform distribution, and supply of an individual producer is inelastic. Specifically, suppose that the project's i output is $[M_o]^{\beta}(1 + \varepsilon_i)$, where M_o is exogenously given (assuming that the producer financed earlier the cost of the variable input, $p_m M_o$).[4] In Section 4 we review the case of endogenous supply.

3. Financial spreads, volatility and heterogeneity

We proceed with a review of several simulations of the case where shocks follow a uniform distribution. All the results inferred can be verified analytically (see the appendix for an overview of the derivation).

The volatility of the productivity shock plays a key role in determining financial spreads. This can be seen in Fig. 3I, which plots the equilibrium interest rates as a function of the standard deviation of the distribution for the case of two producers whose cost of state verification differ (C = 0.1 and C = 0.08).[5] We assume first the absence of a collateral (L = 0). Curve LL corresponds to a lower cost of state verification, and HH to a higher cost. In general, the interest rate/volatility curve is backward bending, and a given volatility may be associated with two interest rates. This follows from the presence of a trade off between the interest rate and the frequency of full repayment.[6] Note that the efficient point is associated with the lower interest rate, as more frequent default is associated with a lower expected surplus (see (8)). Henceforth we will assume that competitive banks choose the efficient point, and we will ignore the backward bending portion of the curves.

Volatility has a profound effect on the interest rate. As Fig. 3I reveals, this effect is more profound for agents whose state verification cost is higher (see Appendices A and B for further analytical discussion). In fact, for large enough volatility, projects characterized by relatively large state verification costs will not be financed.[7] Our example focuses on the uniform distribution, yet its message is general. This follows from the expected break-even condition determining the interest rate, (5). It can be rewritten as

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[4] Note that even if the potential supply is inelastic, volatility will induce welfare costs. First, as (8) reveals, more frequent partial defaults lead to welfare loss due to more costly financial intermediation (note that the expected cost of financial intermediation is C times the probability of default). Second, as we will show shortly, volatility will terminate some projects that are viable in its absence, leading to large welfare losses.

[5] It can be shown that the standard deviation of the uniform distribution is $(E/\sqrt{3}) \cong 0.58E$.

[6] A higher interest rate would increase the probability of default, implying that the net effect of a higher interest rate on the expected repayment is determined by elasticity considerations.

[7] These considerations also imply that the simulations reported in Fig. 3 are sensitive to the choice of parameters. This follows from the observation that the range where the supply of credit is upwards sloping depends on all the parameters of the model. This sensitivity is due to the inherent non-linearity of the supply of credit. As Appendix B illustrates, the qualitative results of our analysis are applicable to all distributions.

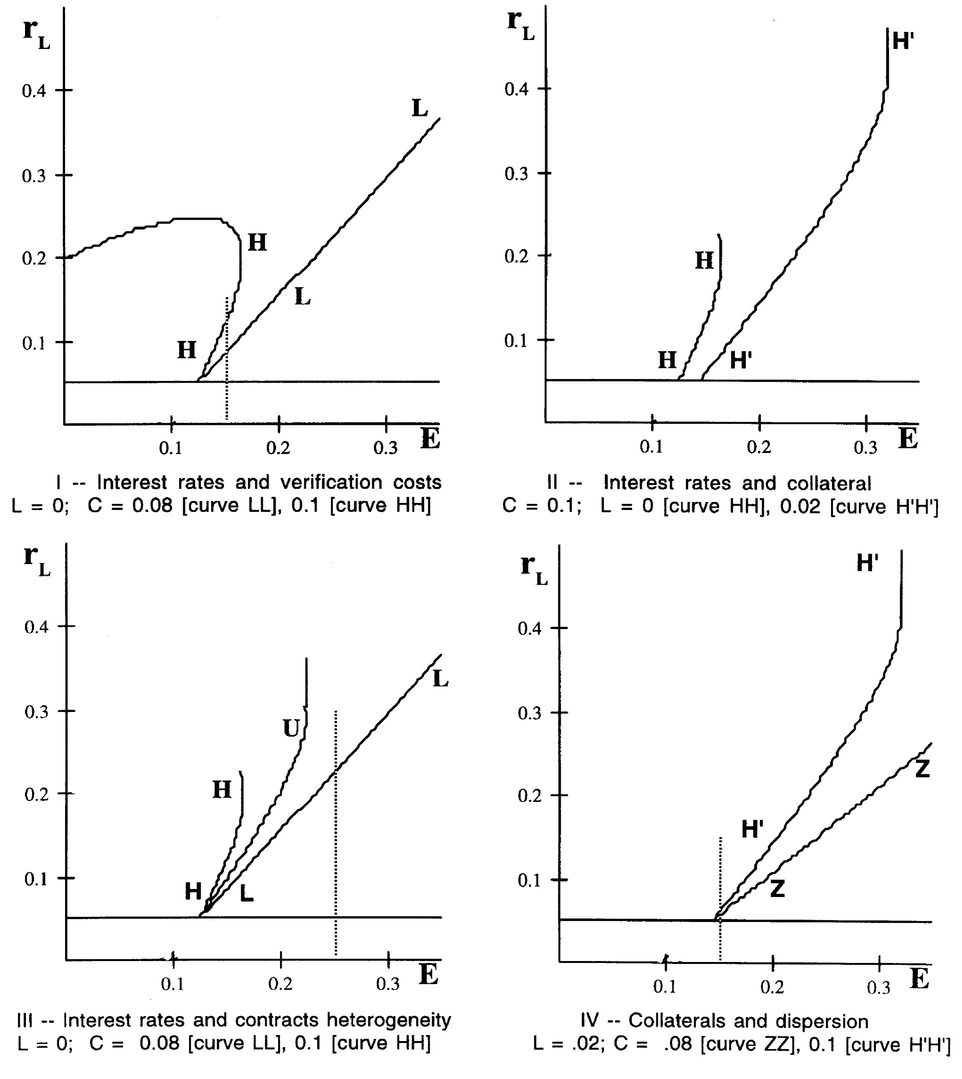

Fig. 3. Interest rate-volatility curves drawn for $\kappa = 0.6$; $M_o = 1$; $r_0 = 0.05$; $p_m = 0.5$.

$$(1 + r_0)M_i p_m = \int_{-E}^{\varepsilon_i^*} R_i(\varepsilon)\ f(\varepsilon)d\varepsilon - C_i \int_{-E}^{\varepsilon_i^*} f(\varepsilon)d\varepsilon \tag{5”}$$

where $R_i(\varepsilon)$ is defined by

$$R_i(\varepsilon) = \min\{(1 + r_{L,i})M_o\ ;\ \kappa[M_0]^{\beta}(1 + \varepsilon) + L_i\} \tag{10}$$

$$= \begin{cases} \kappa[M_o]^{\beta}(1 + \varepsilon) + L_i & if\, \varepsilon_i^* > \varepsilon \\ M_o(1 + r_{L,i}) & if\, \varepsilon_i^* \leq \varepsilon \end{cases}$$

The properties of the $\min\{(1 + r_{L,i})M_o \; ; \; \kappa[M_0]^\beta(1 + \varepsilon_i) + L_i\}$ function imply that the repayment is concave with respect to the realized productivity. Consequently, higher volatility will reduce the expected repayment, reducing the RHS of (5”). This would induce banks to charge a higher interest rate, to offset the drop in expected repayment. Note that the higher interest rate would also increase the probability of default, reducing thereby the net expected repayment by the increase in the expected outlay on monitoring costs, $C_i f(\varepsilon_i^*) d\varepsilon_i^*$ (see (5”)). Hence, the ultimate increase in interest rate must be high enough to compensate for both the drop in expected repayment and for the increase in expected monitoring costs. Consequently, we expect that higher monitoring costs would magnify the needed increase in interest rate. Depending on the values of the various parameters, a significant enough volatility may imply that financing the project is too risky, as would be the case if the bank’s expected income would be negative at all interest rates. See Appendix B for a formal derivation of these results for a general distribution.

The consequences of submitting a collateral are summarized in Fig. 3II, which corresponds to the case where $C = 0.1$, and the collateral levels are either 0 or 0.02. The infusion of collateral shifts the schedule HH rightwards and upwards, to H’H’. The shift is non uniform; it is more profound for higher volatility and for higher interest rates. Hence, collateral infusion alleviates the financing constraint, and reduces the interest rate for a given volatility.

Fig. 3III evaluates the characteristics of a pooled equilibrium, where banks offer a homogenous loan contract. Such an equilibrium is observed if the borrower’s type is private information, hence the banks cannot distinguish between the various borrowers (alternatively, if banks are prohibited from ‘discriminating’ among borrowers). Schedules LL and HH are identical to the ones in Fig. 3I. Schedule U depicts the volatility--interest rate schedule observed in the pooled equilibrium, assuming that borrowers are evenly divided between agents whose $C = 0.1$ and $C = 0.08$. Contract homogeneity taxes the low state verification cost agents, and subsidizes the high state verification cost agents (in comparison to the benchmark of heterogeneous contracts). If the volatility is large enough, loan homogeneity has profound effects beyond affecting the redistribution of income. For example, if E = 0.25 (depicted by the dotted line in Fig. 3III), banks offering homogenous contracts would not break even at any interest rate. Note, however, that at E = 0.25 the credit market would finance the low cost agent if contracts can reflect agent heterogeneity. Hence, volatility increases the costs of loan homogeneity.

To get a better grasp of the impact of collateral on the dispersion of spreads, we reproduce Fig. 3I for the case where agents whose $C = 0.08$ or 0.1 submit a collateral $L = 0.02$ (recall that Fig. 3I focused on agents whose $C = 0.08$ or 0.1, $L = 0$). A comparison of Fig. 3I and IV reveals that more collateralized loans are characterized by a smaller dispersion of observed spreads (for a given heterogeneity of state verification costs). For example, if E = 0.15 (depicted by the dotted line in Fig. 3I and IV, the interest rate differential between the two agents is close to zero with collateral $L = 0.02$, and about 4% in the absence of collateral. Hence, we should expect a lower dispersion of financial spreads in collateralized loans, and this difference is more profound in countries characterized by higher volatility.[8]

4. Volatility and the output response

In the previous section we assumed an exogenously given level of inputs used in the production process. In this section we review the implications of a volatile productivity, allowing for an endogenous adjustment of inputs. Specifically, we would identify the adjustment of the demand of inputs to the volatility of shocks, and the resultant change in the expected final output level. Recall that the expected profits are

$$[M_i]^\beta - (1+r_0)p_m M_i - C_i\Phi_i, \left[\text{recall that } \Phi_i = \frac{\mathrm{E}+\varepsilon_i^*}{2\mathrm{E}}\right]. \tag{11}$$

Applying (6'), we infer that in the range of partial default

$$\Phi_i = 1 - \frac{C_i + \sqrt{\{C_i - 2\kappa[M_i]^\beta \mathrm{E}\}^2 - 4\kappa[M_i]^\beta \mathrm{E}[(1+r_0)p_m M_i - L_i - \kappa[M_i]^\beta(1-\mathrm{E})]}}{2\kappa[M_i]^\beta \mathrm{E}}. \tag{12}$$

Let us denote by E^* the volatility threshold leading to default (i.e. $\Phi_i = 0$ for $E = \mathrm{E}^*$, and $\Phi_i > 0$ for $E > \mathrm{E}^*$. This would be the case if in the worst realization of productivity shock ($\varepsilon = -\mathrm{E}^*$), the penalty associated with partial default would equal the input cost (inclusive of the financing cost), $\kappa[M_i]^\beta(1-\mathrm{E}^*) + L_i = (1+r_0)p_m M_i$. The value of $\mathrm{E}*$ is obtained by finding the volatility that satisfies $\kappa[M_i]^\beta(1-\mathrm{E}^*) + L_i = (1+r_0)p_m M_i$ and the condition for optimal use of the variable input. This would be the case if the expected marginal product of M equals its price, $\beta[M_i]^\beta = (1+r_0)p_m M_i$. Solving these two equations we find that[9]

$$\mathrm{E}^* = MAX\left\{0, \frac{\kappa-\beta}{\kappa} + \frac{L_i}{\kappa M^\beta}\right\} = MAX\left\{0, \frac{\kappa-\beta}{\kappa} + \frac{L_i}{\kappa}\left[\frac{(1+r_0)p_m}{\beta}\right]^{\frac{\beta}{1-\beta}}\right\}. \tag{13}$$

In the absence of collateral, the volatility default threshold depends positively on creditors' power within the legal system (as measured by κ, the fraction of the project's value that can be seized by creditors), and negatively on the importance of working capital (as is depicted by the share of the variable input β). The volatility

[8] For example, if $E = 0.2$, projects characterized by relatively high state verification costs would not be financed in the absence of collateral (hence, if $L = 0$, the gap between the spreads corresponding to $C = 0.1$ and 0.08 is infinite), whereas the gap between the corresponding financial spreads will be about 6% with $L = 0.02$. For further analysis on the importance of internal financing in mitigating the adverse effects of costly monitoring see Bernanke and Gertler (1989).

[9] An alternative way to obtain (13) is by a finding value of $\mathrm{E}*$ that satisfies $\Phi_i = 0$ and $\beta[M_i]^\beta = (1+r_0)p_m M_i$.

threshold increases for collateralized loans by the (collateral/output subject to confiscation) ratio.

For E > E*, the producer would compare the expected profits in two possible regimes. In the first, the producer would find occasional partial defaults optimal. In these circumstances, the optimal employment of the variable input is found by maximizing (11), where the default probability is given by (12). In the second regime, the producer would prefer to scale down the use of input M_i to a level low enough to ensure that no default will take place in the worst state. The corresponding demand for M_i is determined by the condition $\kappa[M_i]^{\beta}(1-\mathrm{E}) + L_i = (1 + r_0)p_m M_i$. The producer will choose the regime that would be associated with higher expected profits.

Fig. 4 plots a simulation of the variable input employment as a function of volatility, for the case where the variable input share exceeds the creditors' power within the legal system measure ($\beta < \kappa$), and the collateral is zero. The bold curve is the employment volatility schedule. The contours in panel I report the probability of default at the various points, drawn for intervals of 0.1, as is determined by (12). The contours in panel II report the 'expected welfare ratio,' defined by the expected producer's surplus relative to the producer's surplus in the absence of volatility. The welfare cost of volatility is obtained by the difference between 1 and the 'expected welfare ratio.' The effects of volatility on the demand for the variable input (M) is negative and large. From point A to point B, the producer cuts M's employment at a rate needed to prevent the possibility of default in the worst state of nature (hence, $\kappa[M_i]^{\beta}(1-\mathrm{E}) = (1 + r_0)p_m M_i$ and $\Phi_i = 0$ along AB). We may refer to curve AB as

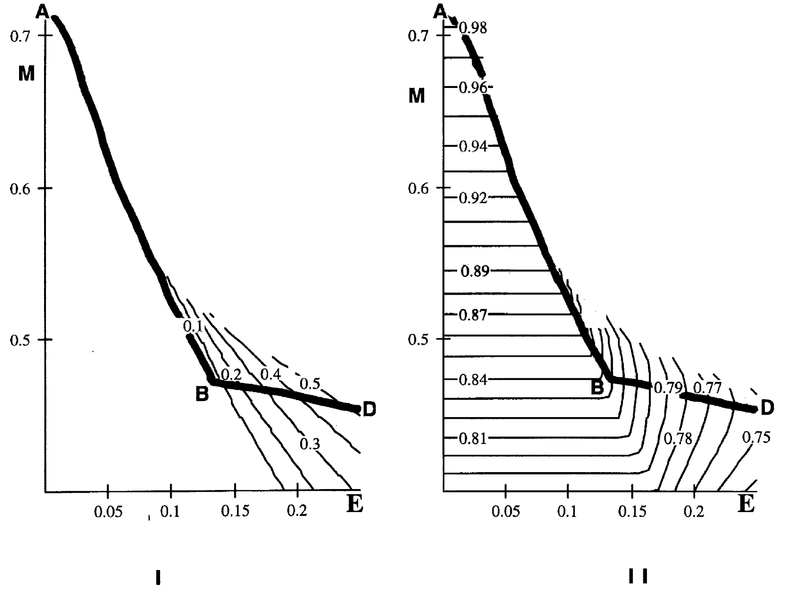

Fig. 4. Volatility and variable inputs plotted for $\beta = 0.7$; $\kappa = 0.55$; $r_0 = 0$; $p_m = 0.6$; $C = 0.05$; $L_i = 0$. The bold curve is the volatility-employment schedule. The contours in (I) report the probability of default. The contours in (II) report [expected producer's surplus]/[producer's surplus in the absence of volatility].

the region of a quasi 'voluntary' credit squeeze, where producers reduce employment as a mechanism to prevent costly default. Comparing points A and B reveals that increasing volatility from zero to E = 0.13 reduces the producer's expected surplus by about 16%, and reduces employment of the variable input by about a 1/3. At a certain stage (point B), the benefits of default outweigh the costs of state verification, inducing a default. The default option mitigates the costs of volatility, as it shifts the burden of servicing the marginal debt to relatively good states of nature. This implies that further increase in volatility would reduce M's employment along BD at a lower rate than along AB.

Fig. 5 reproduces the simulation of Fig. 4 for the case where the creditors' power within the legal system measure exceeds the share of the variable input ($\beta > \kappa$).[10] In these circumstances volatility matters only when it exceeds the threshold $\frac{\kappa-\beta}{\kappa}$ = 0.166 (see (12)). As in Fig. 4, from point A to point B the producer cuts M's employment at a rate needed to prevent the possibility of default in the worst state of nature—a quasi 'voluntary' credit squeeze. In this range volatility induces relatively large adverse employment effects. At point B we switch to the partial default regime, where the benefits of a default option outweigh the costs of state verification. A further increase in volatility would increase M's employment, although it would

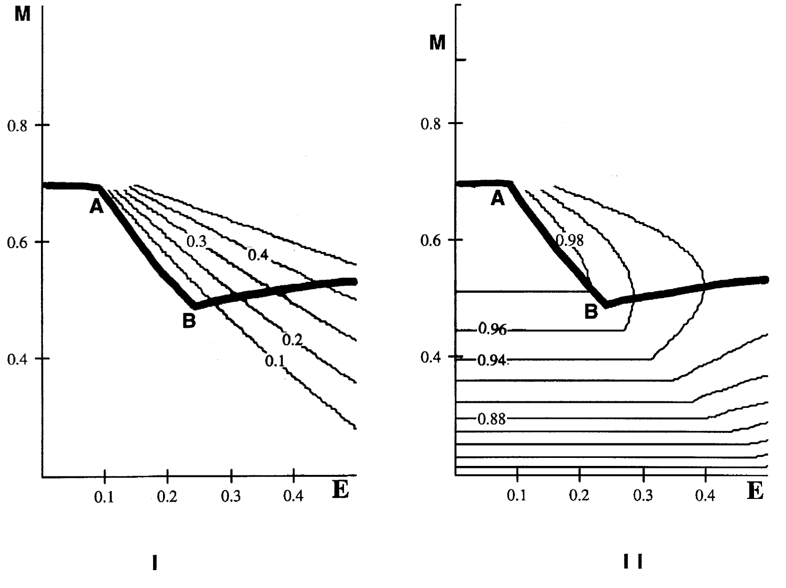

Fig. 5. Volatility and variable inputs plotted for $\beta = 0.5$; $\kappa = 0.55$; $r_0 = 0$; $p_m = 0.6$; $C = 0.05$; $L_i = 0$. The bold curve is the volatility-employment schedule. The contours in (I) report the probability of default. The contours in (II) report [expected producer's surplus]/[producer's surplus in the absence of volatility].

[10] The only difference between the two figures is due to a change in the variable input share (β is 0.7 and 0.5 in Figs. 4 and 5, respectively).

remain below the demand level at point A. This result differs from the one in Fig. 4, where beyond point B higher volatility reduced employment of the variable input. The reason for the difference is that higher volatility has two conflicting effects. First, more frequent defaults increase the cost of employing the variable input, reducing employment. Second, the higher volatility raises the expected marginal product of M, as the marginal product is convex with respect to employment.[11] When the variable input share is smaller, the second effect is more profound, as the convexity of the marginal product is larger. For a small enough share, the second effect dominates, as is the case in Fig. 5. Note that independently from the direction of the adjustment of employment, higher volatility reduces welfare in both cases. In interpreting these results, one should keep in mind that they deal with an atomistic agent, for the case where the relative price of M is given. For a statement about the volatility of aggregate employment a more general model would be needed (where for example p_m would be endogenous).

The above simulations illustrate that the costs of volatility depend crucially on the interaction between several factors—the costs of financial intermediation, creditors' power within the legal system, and the share of variable inputs. Weaker legal system (implying a small κ), a more costly verification of information and legal enforcement (large C), and a large share of the variable input (large β) increase the welfare cost of volatility. The combination of the three would imply that volatility may induce large, first order welfare and employment costs, as is illustrated in Fig. 4. We turn now to a more formal assessment of the welfare cost of volatility.

4.1. Volatility, costly intermediation and welfare

We focus our attention on the case where the share of the variable input exceeds the creditors' power within the legal system measure ($\kappa < \beta$), as one may presume is the case in developing countries. An example of this case was depicted by Fig. 4. Appendix C investigates the case where $\kappa \geq \beta$ (corresponding to Fig. 5). We evaluate now the welfare cost of volatility, where the relevant welfare measure for the risk neutral entrepreneurs is the expected producers surplus (11). Recall that for relatively low volatility, we observe the quasi 'voluntary' credit squeeze along curve AB, where $\kappa[M_i]^{\beta}(1-\mathrm{E}) = (1 + r_0)p_m M_i$ and $\Phi_i = 0$. Applying this to (11), collecting terms, we infer that the expected producer's surplus along AB, denoted by Π, is

$$\Pi = [(1 + r_0)p_m]^{-\beta/(1-\beta)}[[\kappa(1-\mathrm{E})]^{\beta/(1-\beta)} - [\kappa(1-\mathrm{E})]^{1/(1-\beta)}]. \quad (14)$$

From which we obtain that in the vicinity of E = 0

$$\frac{\partial \log \Pi}{\partial \mathrm{E}}_{|\mathrm{E}=0} = -[\frac{1}{1-\beta} - \frac{1}{1-\kappa}]. \quad (15)$$

[11] Recall that in a Cobb-Douglas function the marginal product schedule is convex with respect to employment, and its elasticity (in absolute terms) is $1-\beta$. Hence, the convexity diminishes as the share of the variable input raises.

Note that the standard deviation of productivity $(1 + \varepsilon_i)$ is $\frac{E}{\sqrt{3}}$, and the mean is 1. Hence, the semi-elasticity of the welfare cost with respect to productivity's coefficient of variation is

$$\frac{\partial\Pi/\Pi}{\partial E/\sqrt{3}}\Big|_{E=0} = -\sqrt{3}\frac{\beta-\kappa}{(1-\beta)(1-\kappa)}. \qquad (15')$$

The welfare cost of volatility in the range of credit restraints is proportional to the difference between the variable input share (β) and the creditors' power within the legal system measure (κ).[12] An alternative way of presenting the welfare cost is as a fraction of output, Y:

$$\frac{\partial\Pi/Y}{\partial E/\sqrt{3}}\Big|_{E=0} = -\sqrt{3}\left[\frac{\beta-\kappa}{1-\kappa}\right]. \qquad (16)$$

For example, if the variable's input share is 0.75, and the legal system's strength measure is 0.25, then $\frac{\partial\Pi/Y}{\partial E/\sqrt{3}}\Big|_{E=0} = -1.15$. In these circumstances, a 1% increase in the coefficient of variation of productivity shocks would reduce welfare by more than 1%. Note that the above calculation is a lower estimate of the welfare cost, as it focuses only on the welfare cost attributed to the decline in the entrepreneur's surplus, ignoring the welfare cost due to higher unemployment. It is interesting to note the different roles played by the strength of the legal system (κ) in comparison to that of the cost of state verification (C). Both κ and C are determining the probability of default on the upward sloping portion of the supply of credit (see (12)). Yet, only the strength of the legal system determines the elasticity of the welfare cost with respect to volatility in the range of the 'quasi-voluntary' credit ceiling (as can be seen from (15)). This follows from the observation that in this range, the downward adjustment of employment prevents costly defaults, hence there is no need to verify the state of nature, and the size of C is not relevant. The magnitude of the drop in employment needed to prevent the partial default, however, is larger for weaker legal systems.[13]

5. Policy conclusions

Our analysis has highlighted several features. First, we have developed a model which is capable of explaining both high spreads and also a high dispersion of spre-

[12] Note that β is the share of the variable input financed via borrowing, and κ is the output share that can be used as effective collateral. Greater discrepancy between β and κ increases banks exposure, implying that volatility is more costly.

[13] A weaker legal system implies that a given increase in volatility will induce a greater partial default in bad times, requiring a greater drop in borrowing if one wishes to avoid such partial defaults.

ads across different client types. These results come from assumptions regarding imperfect information (costly state verification) and imperfect enforcement (a limited legal penalty in a 'willingness to pay' type context with bargaining). We conjecture that such imperfections may be client-dependent and hence variations in the relevant variables may explain cross-sectional dispersion in credit spreads. Second, we have found that the effects of volatility on economies may be amplified in this context of imperfect financial intermediation. Here, we find that the weaker the legal system in protecting the rights of creditors (low bank bargaining power) the more pronounced the effect of volatility. Furthermore, where production is dependent on a variable input (e.g. labor), the greater is the share of that input, then the greater may be the effect of volatility. We also analyzed the role of collateral in the context of this model and found that collateral is a crucial tool to lower spreads and to lower the dispersion of spreads.

These results have strong policy conclusions, deserving further exploration. First, they suggest that attempts to give greater powers to borrowers viz-à-viz banks may be misplaced not only in terms of increasing banking spreads, but also in terms of the macroeconomic effects of volatility on the economy. In short, giving too much bargaining power to borrowers in credit market relations may increase unemployment (considering labor as the variable input) in the face of an external shock. An efficient legal system and in particular, the protection of creditor rights, appears to be a determining feature of how the credit market, and hence the economy, in general responds to external shocks. One should keep in mind, however, that our paper focused on the optimal adjustment of the atomistic producer, taking relative price of the factor input (M) as given. Hence, it does not deal directly with the general equilibrium effects of volatility on aggregate employment and aggregate supply. Exploring these issues is left for future research.

Our results also illustrate the importance of information in credit markets. A credit market with little information on creditors and hence high state verification costs will be one characterized by high lending spreads and a high dispersion of spreads. In this regard it seems that policies to enhance information provision such as the setting up of a public or subsidized credit-bureau may be a useful policy response. Public provision may be required as it is not always in the interests of private borrowers to share information. On the one hand, there is a benefit from a risk reduction viewpoint, but on the other there is a cost that others may learn about a private banks' clients hence reducing the banks' rents. In emerging market economies it may be that such rents are indeed high and hence private provision of such information sharing technologies may be at less than the socially optimal level of supply. This may then support a public intervention either in the form of direct provision or the subsidy of private provision or some mixed type of arrangement.

In Argentina, for example, the Central Bank has set up a very extensive credit bureau which now includes the records of some 18 000 large debtors (loans of more than \$200 000) and almost 4 million small debtors. Reports are collected on a monthly basis and the information on non-performing clients (in arrears of more than 90 days) is shared throughout the financial system. Financial intermediaries may also make punctual inquiries about particular borrowers, normally following a loan request, and in this case the exact status of all of the debts of that client throughout the banking system is revealed, i.e. both non-performing loans and also loans that are not in arrears. The Central Bank has recently extended the data asked of the financial intermediaries for larger borrowers to include further client information to allow more sophisticated credit scoring techniques to be employed.

Finally, our model highlights the very important role of collateral. Collateral serves to both lower spreads and also to homogenize them across the market. In a model where imperfect competition was present, as opposed to our perfect competition case, we might also therefore conjecture that collateral might have the effect of increasing competition in the sense that it would reduce the possibility of discrimination across client types. Policies may also be required to improve the working of collateral.

Again, considering Argentina as an example, there is evidence that some types of secured loans are preferred by creditors rather than others. For example, car loans appear to function reasonably well with relatively low rates of interest and swift and reasonable credit authorization procedures. On the other hand some types of secured lending appear to be subject to high interest rates and slow and cumbersome procedures. Important examples include agricultural lending secured on livestocks or commodities, and also lending with some type of working machinery as collateral. There is some evidence that in the case of the agricultural sector, lending from private banks has been substituted by suppliers' credit, largely from the big cereal or feed companies and one might conjecture that repeated relationships and client knowledge is then being used rather than collateral in order to obtain better loan recovery rates. What appears to be happening here is that where legal security is good (e.g. on cars where there is a national register and hence a unique identification of the good and legal protection of the good subject to the loan contract appears to be reasonably complete), then collateral serves its purpose and has the effects as suggested in our model above. On the other hand, where the legal security is poor, collateral does not serve its purpose well and hence is either not used or is used but subject to high spreads. Collateral in these instances does not have the effect as suggested by our theoretical discussion above. The conclusion is then that collateral is important, but can only serve its purpose if creditors' legal security on the good in question is tight. Moreover, there is little point in having excellent legal security if the processes required to seize and make a sale of the collateral imply an unreasonable time-horizon. The policy implication is that the legal framework, legal procedures and also other supporting infrastructure (e.g. registers, etc.) must function appropriately for collateral to have the important beneficial effects as identified above.

6. Concluding remarks

Our study integrated the costly state verification model with a bank's lending framework where the enforcement of contracts is partial. This allowed us to focus on the importance of lenders' bargaining power and the costs of verification in explaining the mere existence and the orderly functioning of the credit market. We illustrated that volatility may lead to first order, large welfare costs in economies where financial intermediation is costly, as is the case in many developing countries. The ultimate welfare cost is determined by the interaction between the creditors' power within the legal system, the share of variable inputs, and the costs of state verification and contract enforcement. We provided a detailed example where under plausible assumptions the semi-elasticity of the welfare cost (as a fraction of expected output), with respect to productivity's coefficient of variation exceeds one. In these circumstances, a 1% standard deviation of productivity shock leads to a welfare cost that exceeds 1% of output. This result is consistent with recent empirical studies that found first order adverse effects of volatility measures on private investment and growth (see Aizenman and Marion, 1993; Pindyck and Solimano,1993 and Ramey and Ramey, 1995; Hausmann and Gavin, 1995, and Ghosal and Loungani, 1996). Furthermore, we showed that the legal system in protecting creditors' rights is crucial in determining the effects of volatility on an economy through the financial system. We suggested that increasing borrowers' bargaining power in credit relations may be misplaced in that this may not only increase intermediation spreads, but may also induce a greater impact of volatility on the economy in general.

We conclude with a discussion of several limitations of our analysis. First, we assumed that all agents are competitive, as would be the case if each agent could choose among a large number of banks, and each bank dealt with a large number of small borrowers. In these circumstances, the equilibrium interest rate charged by the bank is determined by the expected break-even condition. Our analysis shows that in the competitive equilibrium, granting more leverage to lenders would improve welfare. Our assumptions were motivated by the recent developments in Latin American countries, allowing easier entry of new banks, including foreign ones. This result, however, may not hold if banks have market power, as would be the case if very few banks serve a region. Our analysis was also considerably simplified by assuming a uniform distribution. Its qualitative message, however, applies to other distributions (see Appendix B for an analytical derivation of some of the paper's results for a general distribution).

We refrained from modeling the sources of volatility. Instead, we took the volatility as exogenously given, focusing on its welfare costs. Understanding the sources of volatility may also be important for inferring certain further policy implications. For example, volatility may stem from unstable domestic fiscal and monetary policy, or from unstable portfolio choices of foreign investors (as elaborated by Calvo and Mendoza (1997)). While the policy implications may differ between the various cases, our study points out that costly financial intermediation magnifies these costs from second order into potentially large magnitudes.[14]

[14] Calvo and Mendoza (1997) simulations resulted with relatively small welfare costs attributed to portfolio instability. Our analysis suggests that adding costly financial intermediation may magnify these costs considerably.

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Appendix A

The purpose of this appendix is to review analytically the factors determining financial spreads. Eqs. (3) and (6') are the two conditions determining simultaneously $r_{L,i}$; ε_i^* as a function of the economic environment—the volatility, the state verification and enforcement cost, and the collateral level (E; C_i; L_i). In this appendix we apply these conditions to characterize the factors determining the position of the financial spreads--volatility curve. For given borrowers' characteristics (C_i; L_i), the impact of higher volatility on financial spreads is found by applying (5) for the case where $f(\varepsilon) = \frac{1}{2\mathrm{E}}$

$$\frac{dr_{L,i}}{d\mathrm{E}} = \left[\Phi + \frac{C_i}{1-[\Phi + \frac{C_i}{\kappa[M_o]^\beta 2\mathrm{E}}]}\frac{1-\Phi}{\kappa[M_o]^\beta 2\mathrm{E}}\right]\frac{\kappa[M_o]^\beta}{p_m M_o} \quad \text{(A1)}$$

where $\Phi = \frac{\mathrm{E} + \varepsilon_i^*}{2\mathrm{E}}$ is the probability of default. Eq. (A1) implies that a project that is viable for low volatility becomes non-viable when the volatility approaches a threshold. This 'non-viability threshold' is reached when $\frac{dr_{L,i}}{d\mathrm{E}} \rightarrow \infty$, or when $\left[\Phi + \frac{C_i}{\kappa[M_o]^\beta 2\mathrm{E}}\right] \rightarrow 1$. Consequently, the economy operates on the upwards sloping portion of the curve as long as $\Phi + \frac{C_i}{\kappa[M_o]^\beta 2\mathrm{E}} < 1$. Along this portion, higher volatility increases the financial spread at a rate that depends positively on the cost of state verification and enforcement.[15]

[15] Recall that due to efficiency considerations banks are assumed to operate only on the upwards sloping portion of this curve. It can be shown that if $\frac{C_i}{\kappa[M_o]^\beta 2\mathrm{E}} > 1$ at the lowest debt level associated with default, the credit ceiling is reached at that debt level. In these circumstances the supply curve has an inverted L shape. This would be the case if verification costs are too large to be recovered, hence the bank would not supply credit levels that would lead to default in some states of nature. In this appendix we assume that this is not the case.

For a given volatility, the impact of the collateral on financial spreads is

$$\frac{dr_{L,i}}{dL_i} = -\frac{\Phi + \dfrac{C_i}{\kappa[M_o]^{\beta}2\mathrm{E}}}{1-(\Phi + \dfrac{C_i}{\kappa[M_o]^{\beta}2\mathrm{E}})}\frac{1}{p_m M_o} < 0. \tag{A2}$$

The drop in financial spreads induced by a higher collateral increases nonlinearly with $\Phi + \dfrac{C_i}{\kappa[M_o]^{\beta}2\mathrm{E}}$, which in turn depends positively on the cost of intermediation (C) and on the volatility. Hence, a higher collateral level shifts the spread-volatility curve rightwards and downwards. This shift is more pronounced for higher volatility, as is portrayed in Fig. 3II. In a similar way one can confirm that in the relevant range $\dfrac{dr_{L,i}}{dC_i} > 0$; $\dfrac{dr_{L,i}}{d\kappa} < 0$.

Finally, we assess the impact of a collateral on the distribution of financial spreads. This is done by identifying the cross effect of the collateral on the responsiveness of financial spreads to the cost of financial intermediation. It can be shown that

$$\frac{d^2 r_{L,i}}{dL_i dC_i} = -\frac{1}{\left[1-\Phi-\dfrac{C_i}{\kappa[M_o]^{\beta}2\mathrm{E}}\right]}\frac{1}{p_m M_o \kappa[M_o]^{\beta}2\mathrm{E}} < 0. \tag{A3}$$

Consequently, a higher collateral level implies that a given cost heterogeneity is manifested as smaller financial spread heterogeneity. Note that this effect increases nonlinearly with $\Phi + \dfrac{C_i}{\kappa[M_o]^{\beta}2\mathrm{E}}$. Hence, (A2) and (A3) show that the impact of higher collateral level and of lower costs of financial intermediation is maximized as we approach the financial nonviability constraint.

Appendix B

The purpose of this appendix is to derive the results described in Section 3 for a general distribution. Specifically, suppose that the productivity shock impacting producer i is $\varepsilon_i(1 + z)$, where z is a multiplicative term, the size of which determines the variance of the productivity shock ($z \geq 0$). Recall that the expected value of ε_i is zero. Consequently, $dz > 0$ induces a mean preserving increase in the volatility of ε_i. We denote by PR_i the bank's expected rent on project i. The brake even condition determining the interest rate is

$$PR_i = \int_{\varepsilon_i^*}^{\mathrm{E}} [(1 + r_{L,i})p_m M_0] f(\varepsilon) d\varepsilon + \int_{-\mathrm{E}}^{\varepsilon_i^*} [\kappa[M_0]^{\beta}(1 + \varepsilon(1 + z)) + L_i \tag{B1}$$

$$-C_i] f(\varepsilon) d\varepsilon - (1 + r_0) M_0 p_m = 0,$$

where the corresponding productivity threshold associated with default, ε_i^*, is defined by

$$\kappa[M_0]^\beta(1 + \varepsilon_i^*[1 + z]) + L_i = (1 + r_{L,i})p_m M_0. \tag{B2}$$

Alternatively,

$$\varepsilon_i^* = \left\{\frac{(1 + r_{L,i})p_m M_0 - L_i}{\kappa[M_0]^\beta} - 1\right\}\frac{1}{1 + z}. \tag{B2'}$$

Applying (B1) and (B2), we find that a mean preserving increase in the variance of productivity shocks will change the interest rate according to

$$\frac{dr_{L,i}}{dz} = -\frac{\partial PR}{\partial z}\Big/\frac{\partial PR}{\partial r_{L,i}} = \frac{-\kappa[M_0]^\beta \int_{-\mathrm{E}}^{\varepsilon_i^*} \varepsilon f(\varepsilon)d\varepsilon + C_i f(\varepsilon_i^*)}{p_m M_0 \int_{\varepsilon_i^*}^{\mathrm{E}} f(\varepsilon)d\varepsilon}. \tag{B3}$$

Note that $\int_{-\mathrm{E}}^{E} \varepsilon f(\varepsilon)d\varepsilon = 0$, hence $\int_{-\mathrm{E}}^{\varepsilon_i^*} \varepsilon f(\varepsilon)d\varepsilon < 0$. Consequently, more volatile shocks would increase the equilibrium interest rate

$$\frac{dr_{L,i}}{dz} > 0. \tag{B4}$$

Eq. (B3) implies that the interest rate hike induced by the higher volatility increases with the size of the enforcement costs, C. Note that a lower collateral implies a higher probability of default (see (B2')). The higher probability of default is associated with a higher ε_i^*, which in turn will increase the numerator of (B3), and would reduce the denominator, increasing thereby the responsiveness of the interest rate to the volatility of shocks. Consequently, a lower collateral would increase the rise in the interest rate induced by a mean preserving increase in volatility.

Appendix C

We evaluate now the welfare cost of volatility for the case where the share of the variable input is below the legal system's strength measure ($\kappa \geq \beta$). For exposition simplicity we focus on the case where the collateral is zero. An example of this case was depicted by Fig. 5. In these circumstances, for volatility below the threshold $\mathrm{E}* = (\kappa - \beta)/\kappa$, the probability of default is zero, and volatility does not induce any welfare effects (recall (13)). For volatility that exceeds this threshold, we observe the quasi 'voluntary' credit squeeze along curve AB, where $\kappa[M_i]^\beta(1-\mathrm{E}) = (1 + r_0)p_m M_i$ and $\Phi_i = 0$. The expected producer's surplus along curve AB is given by (14), from which we infer that along curve AB

$$\frac{\partial \log \Pi}{\partial E}\Big|_{Along\ AB} = -\frac{\beta-\kappa(1-E)}{(1-\beta)(1-E)[1-\kappa(1-E)]} \tag{C1}$$

Alternatively, the welfare cost of volatility as a fraction of expected output is

$$\frac{\partial \Pi/Y}{\partial E}\Big|_{Along\ AB} = -\frac{\beta-\kappa(1-E)}{(1-\beta)(1-E)}. \tag{C2}$$

Recalling that at point A, $E = E^* = (\kappa-\beta)/\kappa$. Thus, at $E = E^*$ (the threshold value of volatility associated with credit squeeze), the welfare cost of volatility is zero ($\frac{\partial \log \Pi}{\partial E}\big|_A = 0$). Above this threshold, higher volatility increases the welfare cost of volatility, as is measured by (C2).

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