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CONTAGION AND VOLATILITY WITH IMPERFECT CREDIT MARKETS

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ABSTRACT

This paper interprets contagion effects as a perceived increase (triggered by events occurring elsewhere) in the volatility of aggregate shocks impinging on the domestic economy. The implications of this approach are analyzed in a model with two types of credit market imperfections: domestic banks borrow at a premium on world capital markets, and domestic producers (whose demand for credit results from working capital needs) borrow at a premium from domestic banks—which possess comparative advantage in monitoring the behavior of domestic agents. Financial intermediation spreads are shown to be determined by a markup that compensates for the expected cost of contract enforcement and state verification and for the expected revenue lost in adverse states of nature. Higher volatility of producers' productivity shocks increases both financial spreads and the producers' cost of capital, resulting in lower employment and higher incidence of default. The welfare effects of volatility are non-linear. Higher volatility does not impose any welfare cost for countries characterized by relatively low volatility and efficient financial intermediation. The adverse welfare effects are large (small) for countries that are at the threshold of full integration with international capital markets (close to financial autarky), that is, countries characterized by a relatively low (high) probability of default.

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1 Introduction

The Mexican peso crisis of December 1994 brought turmoil to financial and foreign exchange markets worldwide, but nowhere more dramatically than in Argentina. Between December 1994 and March 1995, prices of Argentine bonds and stocks traded on domestic and international markets fell abruptly. The central bank lost about a third of its liquid international reserves, and the interest rate spread between U.S. dollar-denominated bonds issued by Argentina and U.S. Treasury bills increased sharply, to more than 700 basis points during 1995 (Figure 1), whereas the spread between domestic and U.S. interest rates widened to around 900 basis points during the same period. Turbulences in financial markets escalated very quickly into a full-blown economic crisis: bank deposits and bank credit dropped dramatically, and domestic interest rates (on both peso- and dollar-denominated loans) increased sharply—from about 10 percent to more than 40 percent and 30 percent per annum, respectively, between December 1994 and March 1995. Real GDP fell by almost 5 percent for 1995 as a whole, and unemployment increased sharply (Figure 2). Bank closures and restructuring operations led to a consolidation of the banking system.

Several observers have argued that the collapse of the Mexican peso in December 1994, and the ensuing sharp swing in investors' sentiment toward emerging markets (the so-called Tequila effect), triggered Argentina's economic crisis.[1] Various papers have recently attempted to model contagious shocks of this type. Uribe (1996), for instance, formalizes the Tequila effect

[1] There appears to be some agreement that this shift in market sentiment was not entirely warranted by fundamentals. On the one hand, the real exchange rate had indeed appreciated substantially since the introduction of the Convertibility Plan in April 1991, and the current account deficit (as a share of output) was increasing. On the other, however, inflation was low and falling, output and exports were growing at a relatively high rate (with real GDP growing by more than 7 percent a year between 1991 and 1994), and ample liquid reserves appeared to be available to defend the fixed parity between the U.S. dollar and the peso.

as a situation where domestic agents learn at a given moment in time that, at some point in the future, foreign investors will liquidate their holdings of domestic assets—in effect imposing a binding borrowing constraint on domestic agents. Goldfajn and Valdés (1997) highlight the role of liquidity factors in the spread of exchange market pressures across countries, and shown how currency crises can have contagious effects of the type observed in the aftermath of the peso crisis. Agénor (1997) formalizes a contagious shock as a temporary increase in the autonomous component of the risk premium (reflecting "country risk" factors or exogenous elements in market perceptions) that domestic borrowers face on world capital markets. The real effects of such a shock in Agénor's model are captured by linking the financial sector and the supply side via firms' working capital needs—namely, the need to finance labor costs prior to the sale of output. The model's predictions, under the assumption that the shock was perceived to be of a sufficiently long duration, replicate the main features of Argentina's economic downturn.[2]

The analysis presented in the present paper departs from existing studies in two important ways. First, we model not only distortions on world capital markets but also *domestic* credit market imperfections. We do so by considering a two-level financial intermediation process: domestic banks borrow at a premium on world capital markets, and domestic agents (which consist only of producers) borrow also at a premium from domestic banks. The reason why modeling domestic capital market imperfections is important is well illustrated by the data shown in Figure 3: not only did the "foreign" fi-

[2]In addition to these studies, Kaufman (1996) uses the Stiglitz-Weiss model of credit rationing (see Jaffee and Stiglitz, 1990) to argue that the credit crunch in Argentina resulted from an increase in the share of illiquid borrowers induced by the rise in interest rates, and increased incidence of adverse selection problems. Essentially, banks faced greater difficulties screening out between "safe" and "risky" borrowers, because those borrowers most willing to pay a higher interest rate on loans were precisely those for which the potential risk of default had increased. Catão (1996, p. 6) estimates that problem loans had already exceeded 10 percent of the loan portfolio of all financial institutions by end-1994.

nancial intermediation spread increased sharply in the immediate aftermath of the peso crisis in Argentina (as well as Mexico), but so did the spread between domestic bank lending and deposit rates. As it turns out, the model is capable of accounting for this fact by showing how financial intermediation spreads are related to default probabilities and underlying shocks. Second, instead of modeling contagion effects as a deterministic (and temporary) shift in an exogenous component of the risk premium, we focus, in a stochastic setting, on the case where contagion takes the form of an increase in the volatility of aggregate shocks impinging on the domestic economy—that is, an increase in the range of values that such shocks may take. To the extent that such increases translate into a rise in the probability of default of domestic producers on their loan commitments, domestic and foreign interest rate spreads will tend to rise, leading to a drop in expected output. We are thus able of identifying factors that may have contributed to propagating and magnifying an initial exogenous shock. Our analysis also helps clarify the effects of changes in the expected cost of enforcement of loan contracts, both at the domestic and international levels.[3]

The predictions of our framework are not only consistent with the observed increase in financial intermediation spreads and a contraction in activity in Argentina and Mexico (as discussed earlier) but also with higher volatility of output. Our calculations show indeed that the standard deviation of the cyclical component of industrial output in Argentina increased sharply in the year that followed the collapse of the Mexican peso.[4]

[3]In contrast to some of the existing studies, our model is static and partial equilibrium in nature. In particular, we do not model explicitly consumption decisions or central bank regulations. However, some of these features could be added at the cost of greater complexity, without adding much insight.

[4]The cyclical component of industrial output was calculated by taking the difference between actual output (on a monthly basis) and its trend level, computed with the Hodrick-Prescott filter. The standard deviation of that component increased from 3.4 during the period mid-1991 to end-1993, to 5.4 during 1995 for Argentina. Similar results were obtained for Mexico; the standard deviation of the cyclical component of industrial output

The remainder of the paper proceeds as follows. The process of domestic financial intermediation (which involves producers and commercial banks) is described in Section II. Financial intermediation on world capital markets (involving domestic banks and foreign lenders) is discussed in Section III. Section IV studies the effects of a contagious shock, modeled as an increase in the volatility of the aggregate stochastic shock faced by domestic producers. Section V examines the welfare implications of this shock, by focusing on changes in the expected producers' surplus. Finally, Section VI considers some possible extensions of the analysis and offers some final remarks.

2 Output and the Credit Market

We consider an economy in which two categories of domestic agents operate: producers and commercial banks. Banks are risk neutral and behave identically. The "representative" bank borrows on world capital markets, facing a gross expected cost of funds equal to $1 + \tilde{r}_b^f$, and lends to domestic agents at the contractual gross interest rate $1 + r_L$. Domestic banks have comparative advantage in enforcing repayment of their loans to domestic producers, and are therefore not subject to direct competition from foreign lenders. Thus, producers borrow only from domestic banks, and not directly from foreign lenders.

Output of producer h is a function of labor employed and a composite productivity shock:

$$y_h = n_h^{\beta}(1 + \delta_0 + \delta + \varepsilon_h). \quad \beta < 1 \tag{1}$$

In the above equation, n_h is employment, and δ is an aggregate shock with zero mean and a density function $g(\delta)$ defined over the interval $(-\delta_m, \delta_m)$, with $\delta_m > 0$. ε_h is a producer-specific, idiosyncratic shock with zero mean

increased from 2.6 to 5.5 during the same period as the one considered for Argentina.

and a density function $f(\varepsilon_h)$ defined over the interval $(-\varepsilon_m, \varepsilon_m)$, where $\varepsilon_m > 0$. Since δ and ε_h have zero mean, expected productivity is $1 + \delta_0$.

The process of domestic financial intermediation can be characterized as follows. Producers must finance their entire working capital needs (which consist only of labor costs) prior to the sale of output. They cannot issue claims on their capital stock to finance these needs, and therefore borrow from domestic banks. Total production costs faced by producer h are thus equal to the wage bill plus interest payments made on bank loans needed to pay labor in advance, $wn_h(1 + r_L)$, where w is the going wage (assumed constant). If producer h decides to default on part or all of its debt (after all shocks are realized), domestic banks have the capacity to force him (through appropriate legal actions) to pay a fraction $0 \leq \kappa \leq 1$ of his realized output. Enforcing repayment involves a cost C (measured in units of output) to the bank.[5]

Given this setting, producer h will choose to default if

$$\kappa n_h^{\beta}(1 + \delta_0 + \delta + \varepsilon_h) < wn_h(1 + r_L). \tag{2}$$

If the probability of default is zero, the lending rate is equal to the bank's expected cost of borrowing on world capital markets ($r_L = \tilde{r}_b^f$) and producer h's expected profits are given by

$$n_h^{\beta}(1 + \delta_0) - wn_h(1 + \tilde{r}_b^f). \tag{3}$$

From the first-order condition for profit maximization, optimal employment n_0 is thus given by

$$\beta n_0^{\beta-1}(1 + \delta_0) = w(1 + \tilde{r}_b^f).$$

[5]The enforcement cost can be related, in particular, to the idea of costly state verification (see Townsend, 1979). That is, it costs C to verify the realization of ε_h and to force the producer to repay accordingly. Although C is modeled as a fixed monitoring and enforcement cost per loan, the analysis can be extended to allow for a variable cost, proportional to the size of the loan, without changing the key results derived below. For earlier models of imperfect creditworthiness with costly state verification in a related context, see Aizenman et al. (1996) and Calvo and Kaminsky (1991).

Given that employment is set optimally, equation (2) implies that for the probability of default to be zero over the whole range of realizations of ε_h and δ requires that, setting $\varepsilon_h = -\varepsilon_m$ and $\delta = -\delta_m$:

$$\kappa n_0^{\beta}(1 + \delta_0 - \delta_m - \varepsilon_m) > wn_0(1 + \tilde{r}_b^f),$$

or equivalently, using the firs-order condition given above:

$$\kappa(1 + \delta_0 - \delta_m - \varepsilon_m) > \beta(1 + \delta_0),$$

which can be rearranged to give

$$\delta_m + \varepsilon_m < (1 - \frac{\beta}{\kappa})(1 + \delta_0).$$

We assume in what follows that $\beta/\kappa < 1$. In addition, to make the problem nontrivial, we also assume that $\delta_m + \varepsilon_m$ is sufficiently large to ensure that the above inequality is reversed. Thus, ex ante, some producers are always expected to default on their loan obligations.

The contractual interest rate charged by the representative bank to any given domestic producer r_L is determined by the condition that expected gross repayment from borrower h (evaluated over the whole range of variation of ε_h and δ) the producer be equal to the gross expected value of the loan contracted on world capital markets by the bank—which equals the size of the loan to producer h times the expected cost of funds faced by domestic banks abroad, $1 + \tilde{r}_b^f$:

$$(1 + \tilde{r}_b^f)wn_h = \int_{\delta^*}^{\delta_m} (1 + r_L)wn_h g(\delta)d\delta + \int_{-\delta_m}^{\delta^*} \Phi(\delta)g(\delta)d\delta, \tag{4}$$

where

$$\Phi(\delta) = \int_{\varepsilon^*}^{\varepsilon_m} (1 + r_L)wn_h f(\varepsilon_h)d\varepsilon_h + \int_{-\varepsilon_m}^{\varepsilon^*} (\kappa y_h - C)f(\varepsilon_h)d\varepsilon_h,$$

with

$$\delta^* = \frac{wn_h(1 + r_L)}{\kappa n_h^{\beta}} - 1 - \delta_0 + \varepsilon_m, \quad \varepsilon^* = \frac{wn_h(1 + r_L)}{\kappa n_h^{\beta}} - 1 - \delta_0 - \delta.$$

In the above expressions, the term δ^* is the value of the aggregate productivity shock that induces some producers to default partially; that is, for a realization of the aggregate productivity shock δ satisfying the condition $\delta \leq \delta^*$, some producers will default. In such circumstances, ε^* is the threshold value of the idiosyncratic shock to productivity associated with partial default. We assume that each bank deals with a large number of small independent producers, such that the law of large numbers applies.[6]

The term $\Phi(\delta)$ measures the expected repayment per producer, conditional on a given realization of the macro shock δ; it can be verified that $\partial\Phi(\delta)/\partial\delta > 0$.

Equation (4) can be rearranged to give

$$(1 + r_L)wn_h = (1 + \tilde{r}_b^f)wn_h + \Gamma, \tag{5}$$

where

$$\Gamma = \int_{-\delta_m}^{\delta^*} \int_{-\varepsilon_m}^{\varepsilon^*} \left[\left\{ \kappa n_h^\beta (\varepsilon^* - \varepsilon_h) + C \right\} f(\varepsilon_h) d\varepsilon_h \right] g(\delta) d\delta.$$

Equation (5) shows that the contractual lending rate charged by the representative bank on loans to domestic producers exceeds the bank's expected borrowing cost by a margin that compensates for the expected loss in revenue incurred in states of nature where partial default occurs, as given by the expression $\int_{-\delta_m}^{\delta^*} \left\{ \int_{-\varepsilon_m}^{\varepsilon^*} \left\{ \kappa n_h^\beta (\varepsilon^* - \varepsilon_h) \right\} f(\varepsilon_h) d\varepsilon_h \right\} g(\delta) d\delta$, adjusted for the expected enforcement cost $C \int_{-\delta_m}^{\delta^*} \left\{ \int_{-\varepsilon_m}^{\varepsilon^*} f(\varepsilon_h) d\varepsilon_h \right\} g(\delta) d\delta$. Both terms are evaluated for ε_h, δ in the dotted triangle D in Figure 4, which defines the region where default will occur.

Equation (5) can be rewritten as

$$r_L - \tilde{r}_b^f = \Gamma / wn_h. \tag{6}$$

Let $1 + \tilde{r}_P$ denote the expected gross cost of funds for domestic producer h. This cost is determined from the condition that

[6]That is, banks diversify away the i.i.d. risk.

$$(1+\tilde{r}_P)wn_h = \int_{\delta^*}^{\delta_m}(1+r_L)wn_h g(\delta)d\delta \tag{7}$$

$$+\int_{-\delta_m}^{\delta^*}\left\{\int_{\varepsilon^*}^{\varepsilon_m}(1+r_L)wn_h f(\varepsilon_h)d\varepsilon_h + \int_{-\varepsilon_m}^{\varepsilon^*}\kappa y_h f(\varepsilon_h)d\varepsilon_h\right\}g(\delta)d\delta$$

Using (4), it follows that

$$(1+\tilde{r}_P)wn_h = (1+\tilde{r}_b^f)wn_h + C\,\Pr(d/p), \tag{8}$$

where $\Pr(d/p) = \int_{-\delta_m}^{\delta^*}\left\{\int_{-\varepsilon_m}^{\varepsilon^*} f(\varepsilon_h)d\varepsilon_h\right\}g(\delta)d\delta$ is the probability that any given producer will default. Thus

$$\tilde{r}_P - \tilde{r}_b^f = C\,\Pr(d/p)/wn_h. \tag{9}$$

Producer h's decision problem is to choose employment n_h that maximizes expected profits, which are given by an expression similar to (3) with the contractual lending rate $\tilde{r}_b^f$ replaced by the expected cost of borrowing from domestic banks, $\tilde{r}_P$. Using (7) to eliminate the second term in that expression implies that expected profits can be written as

$$n_h^\beta(1+\delta_0) - \int_{\delta^*}^{\delta_m}(1+r_L)wn_h g(\delta)d\delta$$

$$-\int_{-\delta_m}^{\delta^*}\left\{\int_{\varepsilon^*}^{\varepsilon_m}(1+r_L)wn_h f(\varepsilon_h)d\varepsilon_h + \int_{-\varepsilon_m}^{\varepsilon^*}\kappa y_h f(\varepsilon_h)d\varepsilon_h\right\}g(\delta)d\delta.$$

or more compactly, using (8):

$$n_h^\beta(1+\delta_0) - (1+\tilde{r}_b^f)wn_h - C\,\Pr(d/p).$$

Deriving the above expression with respect to n_h and setting the result to zero gives

$$\beta n_h^{\beta-1}(1+\delta_0) - \left\{(1+\tilde{r}_b^f)w + C(1-\beta)\frac{wn_h^{-\beta}(1+r_L)}{\kappa}\int_{-\delta_m}^{\delta^*} f(\varepsilon^*)g(\delta)d\delta\right\} = 0 \tag{10}$$

We will assume that the shocks ε and δ follow a uniform distribution, so that, with $z = \varepsilon, \delta$, $f(z) = 1/2z_m$, and $\Pr(z > x) = (z_m - x)/2z_m$. We can thus establish the following proposition:

Proposition 1 *Higher volatility and lower expected productivity reduce employment and increase the bank's contractual lending rate:*[7]

$$\frac{\partial n_h}{\partial \delta_m} < 0,\ \frac{\partial n_h}{\partial \varepsilon_m} < 0,\ \frac{\partial n_h}{\partial \delta_0} > 0;\ \frac{\partial r_L}{\partial \delta_m} > 0,\ \frac{\partial r_L}{\partial \varepsilon_m} > 0,\ \frac{\partial r_L}{\partial \delta_0} < 0.$$

Figure 5 illustrates graphically these results. The downward-sloping curve NN represents the combinations of employment and the contractual lending rate implied by the first-order condition (10), whereas the convex curve BB represents the combinations of n_h and r_L associated with zero expected profits by the banks, as implied by (4). The intersection of these two curves gives the pair (r_L, n_h) consistent with (expected) profit maximization by producer h and zero expected profits by the bank on its loan to producer h. Simulation 1 is the benchmark case. Simulation 2 (3) correspond to an increase in the standard deviation of the micro (macro) shock by 50 percent relative to the benchmark case. Simulation 4 corresponds to a drop in expected productivity by 10 percent relative to the benchmark case. Note that a similar adjustment occurs in all these cases—a significant increase in the financial intermediation spread (an increase in r_L relative to $\tilde{r}_b^f$), and a drop in employment. Simulation 5 traces the adjustment to a combination of the above 3 shocks, showing a profound drop in employment and a sharp increase in the financial intermediation spread. Finally, simulation 6 shows the adjustment to a rise in the bank's expected real cost of capital, from 0 to 10 percent. Again, the results are an increase in r_L and a drop in employment.

[7]Proofs of these propositions are available upon request.

3 The World Capital Market

Domestic banks have access to world capital markets and borrow, at the contractual interest rate r_b^*, wn_h per domestic producer. If domestic banks default partially, repaying less than $wn_h(1+r_b^*)$, foreign banks have the ability to force domestic banks to pay a fraction κ_b of the realized revenue $\Phi(\delta)$. Enforcing that repayment involves real costs C_b to the foreign bank.

In this setting, a domestic bank lending to producer h will default if and only if

$$\kappa_b\Phi(\delta) < wn_h(1+r_b^*).$$

Let $\hat{\delta}$ denote the threshold value of the aggregate shock associated with partial default of domestic banks. It is defined implicitly by the condition $\kappa_b\Phi(\hat{\delta}) = wn_h(1+r_b^*)$.

Let r_0^f be the foreign lender's cost of funds, which is equal to the risk-free interest rate in the absence of transactions costs. Under risk neutrality, the interest rate r_b^* charged by foreign lenders to domestic banks is determined by

$$(1+r_0^f)wn_h = \int_{\hat{\delta}}^{\delta_m}(1+r_b^*)wn_h g(\delta)d\delta + \int_{-\delta_m}^{\hat{\delta}}[\kappa_b\Phi(\delta) - C_b]g(\delta)d\delta, \quad (11)$$

which can be rewritten as

$$(1+r_0^f)wn_h = (1+r_b^*)wn_h - \Gamma_b, \quad (12)$$

where

$$\Gamma_b = \int_{-\delta_m}^{\hat{\delta}}[\kappa_b\{\Phi(\hat{\delta}) - \Phi(\delta)\} + C_b]g(\delta)d\delta.$$

From the point of view of the domestic bank, the expected cost of funds $\tilde{r}_b^f$ is determined by the condition

$$(1+\tilde{r}_b^f)wn_h = \int_{\hat{\delta}}^{\delta_m}(1+r_b^*)wn_h g(\delta)d\delta + \int_{-\delta_m}^{\hat{\delta}}\kappa_b\Phi(\delta)g(\delta)d\delta, \quad (13)$$

which shows that the expected cost of capital is the sum of the expected interest repayment in relatively good states of nature (the first term on the right-hand side of the equation) plus the expected repayment in adverse states of nature, when partial default occurs (the second term on the right-hand side).

Combining equations (11) and (13) yields

$$(1+\tilde{r}_b^f)wn_h = (1+r_0^f)wn_h + C_b \Pr(d/b),$$

where $\Pr(d/b) = \int_{-\delta_m}^{\hat{\delta}} g(\delta)d\delta$ is the probability that the representative domestic bank will default. Alternatively, using (11):

$$(1+\tilde{r}_b^f)wn_h = (1+r_b^*)wn_h - \int_{-\delta_m}^{\hat{\delta}} \kappa_b\{\Phi(\hat{\delta})-\Phi(\delta)\}g(\delta)d\delta.$$

From the above results, we have

$$r_b^* - \tilde{r}_b^f = \frac{\int_{-\delta_m}^{\hat{\delta}} \kappa_b\{\Phi(\hat{\delta})-\Phi(\delta)\}g(\delta)d\delta}{wn_h},\ \tilde{r}_b^f - r_0^f = \frac{C_b \Pr(d/b)}{wn_h},\ r_b^* - r_0^f = \frac{\Gamma_b}{wn_h},$$

which, together with (9), can be summarized in the following propositions:

Proposition 2 *The expected cost of funds for domestic banks on world capital markets, and for producers on the domestic capital market, can be written as a markup over the world safe interest rate:*

$$\tilde{r}_b^f = \frac{C_b}{wn_h}\Pr(d/b) + r_0^f,\ \ \tilde{r}_P = \frac{C}{wn_h}\Pr(d/p) + \frac{C_b}{wn_h}\Pr(d/b) + r_0^f.$$

The markup adjusts the lender's cost of capital by the expected cost of contract enforcement and state verification.

Proposition 3 *The domestic and foreign financial intermediation spreads, defined as the difference between the relevant contractual interest rate and the relevant expected cost of funds, are equal to the sum of the expected contract* *enforcement costs plus the expected revenue lost in the adverse state of nature, when partial default will take place:*

$$r_b^* - r_0^f = \frac{\Gamma_b}{wn_h}, \quad r_L - \tilde{r}_b^f = \frac{\Gamma}{wn_h},$$

where Γ *and* Γ_b *are defined in equations (5) and (12).*

4 Volatility and Contagion

Having established the mechanism through which financial spreads, employment and output are determined, we are now in a position to study the adjustment process to a rise in the volatility of macroeconomic shocks. A key feature of a debt contract in our framework is the nonlinear dependency of repayment capacity on the aggregate shock δ. To illustrate this point, recall that domestic banks will default on their foreign debt if $\kappa_b\Phi(\delta) < wn_h(1+r_b^*)$. This condition is plotted in Figure 6, where curve RR draws the debt repayment if banks default, $\kappa_b\Phi(\delta)$, and curve DD plots the repayment due, $wn_h(1 + r_b^*)$. The bold kinked curve depicts actual repayment. Ceteris paribus, higher volatility does not affect repayment in goods states of nature, but increases the incidence and severity of partial default. In terms of Figure 6, higher volatility adds segment Δ to the range of default. The partial equilibrium effect is to increase the probability of default by (approximately) $\Delta/2\delta_m$, thereby reducing expected repayment and raising the expected cost of funds. There is also a general equilibrium effect, which results from the fact that foreign lenders increase the interest rate charged to domestic banks to compensate for lower expected repayment and for the higher expected cost of contract enforcement. This adjustment leads to an upward shift in curve DD, further increasing the incidence of default. The general equilibrium effect therefore magnifies the increase in the probability of default, since it leads also to a rise in the expected cost of funds and a rise in financial intermediation spreads.

A similar analysis applies for the impact of higher volatility on domestic financial intermediation. Thus, by showing how interest rate spreads are related to default probabilities and changes in volatility of underlying shocks, our analysis is capable of explaining not only the increase in "foreign" financial intermediation spreads recorded by Argentina in the immediate aftermath of the peso crisis, but also the sharp increase in the spread between the country's bank lending and deposit rates (see Figure 3).

5 Welfare Effects

We turn now to an evaluation of the impact of contagious factors (or, more precisely here, volatility) on welfare, as approximated by the expected producers' surplus, S_P^e.[8] Suppose that there are N identical producers in the economy. Based on our discussion in the previous section, we can infer that the expected producer's surplus (at the optimal level of employment) is

$$S_P^e = N\left[n_0^{\beta}(1+\delta_0) - (1+\tilde{r}_b^f)wn_0 - C\Pr(d/p)\right]. \tag{14}$$

Consequently, the effect of higher volatility on the expected producer's surplus is given by

$$\frac{dS_P^e}{d\delta_m} = \frac{\partial S_P^e}{\partial n_0}\cdot\frac{\partial n_0}{\partial \delta_m} + \frac{\partial S_P^e}{\partial \tilde{r}_b^f}\cdot\frac{\partial \tilde{r}_b^f}{\partial \delta_m} + \frac{\partial S_P^e}{\partial \Pr(d/p)}\cdot\frac{\partial \Pr(d/p)}{\partial \delta_m}. \tag{15}$$

By virtue of the envelope theorem, the first term on the right-hand side of the above expression is zero (recall that each producer h sets employment so as to maximize S_P^e). Applying Proposition 2, it follows that

$$\frac{dS_P^e}{d\delta_m} = -N\left[C\frac{\partial \Pr(d/p)}{\partial \delta_m} + C_b\frac{\partial \Pr(d/b)}{\partial \delta_m}\right]. \tag{16}$$

[8] A similar analysis would apply to labor, where the ultimate welfare effect of the drop in employment is the drop in employment times the difference between the producers' real wage and the supply price of labor.

The above equation can be reduced to a simple form for the case where the repayment associated with partial default is approximated by a linear function (see the Appendix for details). In the range of partial default, where $\Pr(d/p)$ and $\Pr(d/b)$ are both positive:

$$\frac{dS_P^e}{d\delta_m} = -N\left\{C\frac{1-\Pr(d/p)}{2\delta_m - \frac{C}{\kappa B[1-\Pr(d/p)]}} + \Omega C_b \frac{1-\Pr(d/b)}{2\delta_m - \frac{C_b}{\kappa_b B[1-\Pr(d/b)]}}\right\}, \qquad (17)$$

where B is a constant term measuring the partial effect of δ in the linear approximation to $\Phi(\cdot)$, and Ω is defined by

$$\Omega = \frac{2\delta_m[1-\Pr(d/p)]}{2\delta_m[1-\Pr(d/p)] - \frac{C}{\kappa B}}.$$

Let Pr refer to the probability of default of either domestic producers or domestic banks. Applying (17), it follows that the impact of volatility is large for countries that are on the verge of full integration with global financial markets, since for these countries the expression $1 - \Pr$ is maximized. These countries are in a precarious state—for low volatility the marginal effect of more turbulent markets is zero, but for volatility above a threshold, this effect can be profound. This may explain why countries like Argentina in the early 1990s are the most exposed to volatility. The above equation also implies that higher volatility matters very little for highly risky countries where the probability of full repayment is low—that is, where $1 - \Pr$ is close to zero. Such countries operate to begin with on the relatively inelastic portion of the supply of funds, hence higher volatility has little effect at the margin.

This, in turn, implies a nonlinear association between volatility and the expected producers' surplus, as illustrated in Figure 7 (based on (14)). For small enough volatility (assuming a high enough expected productivity), the probability of default is zero. In these circumstances higher volatility does not impact welfare. Once a threshold is reached (point A), higher volatility increases the probability of default, leading to a welfare loss proportional to the cost of intermediation times $\Delta \Pr$. This nonlinearity may explain why contagious shocks may have highly heterogeneous effects across countries. Suppose that a crisis like the Mexican peso collapse increases financial markets' perception of volatility in developing countries (or emerging markets) in general. The adverse, domestic effects of this perception will differ across countries, even if the perceived increase in volatility is identical across countries. For countries that are viewed as relatively safe, $\Pr = 0$, and the effect is nil. By contrast, for countries that were viewed to begin with as mildly risky ventures ($\Pr > 0$ but close to point A), the effect will be large. By contrast, this adverse effect tends to be smaller for countries whose degree of financial openness is relatively small, since for these countries the probability of default is large.

For a given probability of default, the adverse effect of higher volatility tends to be magnified for countries where the cost of contract enforcement is large. In terms of Figure 7, a larger cost of financial intermediation (C or C_b) is associated with an inward shift of the downward-sloping portion of the curve from the solid portion that starts at point A, to the broken portion that starts at point A'.[9] If the cost of financial intermediation is large enough, the welfare effect of uncertainty would be traced by the dotted curve that starts at point A''. In these circumstances, volatility may lead to a situation akin to credit rationing, where producers are not able to obtain bank financing for their working capital.

[9] As noted by Catão (1996, p. 5), in Argentina severe limitations to the seizure of collateral property still prevails; judicial actions take time and are relatively costly—thereby affecting lending rates by raising the potential cost of default.

6 Summary and Conclusions

The purpose of this paper has been to analyze the transmission process of contagious shocks. In contrast to the existing literature, our model does so by capturing imperfections on both world capital markets and domestic credit markets. Specifically, we assume a two-level financial intermediation process with risk-neutral lenders: domestic banks borrow at a premium on world capital markets, and domestic producers borrow also at a premium from domestic banks. In addition, we offer a different interpretation of contagion effects: in our analysis contagion takes the form of a perceived increase (triggered by events occurring elsewhere) in the volatility of aggregate shocks impinging on the domestic economy—that is, an increase in the range of values that such shocks may take.

Our analysis shows that (both foreign and domestic) interest rate spreads are determined by a markup that compensates for the expected cost of contract enforcement and state verification, and for the expected revenue lost in adverse states of nature. Higher volatility of producers' productivity shocks increases both financial intermediation spreads and the producers' cost of capital, resulting in lower employment and higher incidence of default. In addition, our analysis shows that the welfare effects of an increase in volatility are highly nonlinear. Higher volatility does not impose welfare cost on countries characterized by relatively low volatility and efficient financial intermediation. The adverse welfare effects are large (small) for countries that are at the threshold of full integration with international capital markets (close to financial autarky), that is, countries characterized by relatively low (high) probability of default.

Although our model is static and partial equilibrium in nature, it offers a useful framework for interpreting some of the events that occurred in Argentina in early 1995. In particular, it helps to understand how changes in perceived volatility of aggregate shocks may have played a role in the transmission and magnification of an initial adverse shock on world capital markets.[10] It also highlights the role of domestic factors (such as the cost of contract enforcement) in this process. This prediction is broadly consistent with the analysis of contagion effects by Sachs et al. (1996), whose study focuses on the evolution of 20 emerging market economies in the aftermath of the peso crisis. They emphasized the role of domestic imbalances in countries that suffered the most from speculative attacks, and identified as important factors not only overvalued exchange rates, low foreign exchange reserves, but also a weak banking system.

Our model can be readily extended to account for other relevant factors. For instance, if lenders on both domestic and world financial markets are risk averse, the greater perceived volatility will induce a further increase in interest rate spreads to account for a higher risk premium, magnifying therefore the effect of an increase in the probability of default and the welfare cost of volatility.

[10]Of course, various other factors have also played a role in this process. An increase in the perceived risk of confiscation of bank deposits—as occurred in December 1989, when the government, in an effort to reduce inflation, forced the conversion of time deposits and public sector debt into U.S. dollar-denominated government (BONEX) securities—and the fact that bank deposits were not insured certainly played a role of in the bank run and the credit crunch that took place in early 1995 (see Catão, 1996). There may also have been increased doubts about the sustainability of full convertiblity of current and capital account transactions, as well as perceived constraints on the lender-of-last-resort function of the central bank, under the quasi-currency board in place since the Convertibility Plan of 1991.

Appendix

This Appendix derives the probability of default for the case where the partial repayment function can be approximated by a linear curve. For simplicity of exposition we do it for the case where employment n_h is constant, and focuses on intermediation between foreign lenders and domestic banks.[11]

Suppose that in the relevant region domestic banks' revenue is given by the linear approximation

$$\Phi(\delta) = A + B\delta,$$

with $A, B > 0$. The threshold value $\hat{\delta}$ of the aggregate shock δ that makes producers indifferent between partial default and repayment is thus

$$\kappa_b(A + B\hat{\delta}) = wn_h(1 + r_b^*), \tag{A1}$$

and the probability of bank default is

$$\hat{\delta} = B^{-1}\left\{\frac{(1 + r_b^*)wn_h}{\kappa_b} - A\right\},$$

which implies that

$$\Pr(d/b) = \frac{\hat{\delta} + \delta_m}{2\delta_m}. \tag{A2}$$

Using (11), we infer that

$$wn_h(1 + r_0^f) = wn_h(1 + r_b^*) - \int_{-\delta_m}^{\hat{\delta}} \frac{\kappa_b[\Phi(\hat{\delta}) - \Phi(\delta) + C_b]}{2\delta_m} d\delta,$$

that is

$$wn_h(1 + r_0^f) = wn_h(1 + r_b^*) - \int_{-\delta_m}^{\hat{\delta}} \frac{\kappa_b B(\hat{\delta} - \delta) + C_b}{2\delta_m} d\delta. \tag{A3}$$

[11] Recall that in the expression determining the welfare effects of higher volatility (equation (15)), changes in employment are of secondary importance by virtue of the envelope theorem.

Solving (A3) yields

$$wn_h(1+r_0^f) = wn_h(1+r_b^*) - C_b\frac{\hat{\delta}+\delta_m}{2\delta_m} + \frac{\kappa_b B}{2\delta_m}\frac{(\hat{\delta}-\delta)^2}{2}\Bigg|_{-\delta_m}^{\hat{\delta}},$$

that is

$$wn_h(1+r_0^f) = wn_h(1+r_b^*) - \Pr(d/b)C_b - \kappa_b B\delta_m \Pr(d/b)^2. \qquad \text{(A4)}$$

Applying (A1) and (A2), we solve for the contractual interest rate facing domestic banks in terms of $\Pr(d/b)$. Substituting the result in (A4) yields a quadratic equation for the probability of default:

$$\kappa_b B\delta_m \Pr(d/b)^2 + (C_b - 2\kappa_b B\delta_m)\Pr(d/b) + wn_h(1+r_0^f) - \kappa_b A + \kappa_b B\delta_m = 0$$

Applying the implicit function theorem to this equation yields

$$\frac{\partial \Pr(d/b)}{\partial \delta_m} = \frac{1-\Pr(d/b)}{2\delta_m - \frac{C_b}{\kappa_b B[1-\Pr(d/b)]}}, \qquad \text{(A5)}$$

which can be combined with (16) to give (17).

Note also that, for δ_m given:

$$\frac{\partial \Pr(d/b)}{\partial C_b} = -\frac{\Pr(d/b)}{2B\kappa_b\delta_m[1-\Pr(d/b)] - C_b}.$$

If creditors' capacity to enforce partial repayment is small (that is, if κ or κ_b is small), or if the cost of financial intermediation is large enough, there is no internal solution—that is, the value of Pr that solves the quadratic equation given above is outside the [0,1] interval. Furthermore, for certain parameter values we may observe multiple equilibria, as is the case where there are two values of Pr, satisfying $0 < \Pr < 1$, corresponding to low or high interest rate rates. Henceforth we assume that the model's parameters are such that an internal equilibrium exits. Specifically, we assume that creditors' bargaining power is large enough, and that the cost of financial intermediation is small enough to ensure that the probability of default is zero in the absence of aggregate volatility ($\Delta\delta = 0$), and the probability of default is positive for large enough volatility. We also assume that, in the presence of multiple equilibria, the market chooses the equilibrium associated with the lower interest rate. This is also the equilibrium associated with the lower probability of default and the higher welfare level. It can be shown that these assumptions imply that, in an internal equilibrium satisfying $0 < \Pr < 1$, (A5) is positive.

A similar analysis applies for the impact of higher volatility on the producer's probability of default. The main difference between analyzing the partial effects $\partial \Pr(d/b)/\partial\delta_m$ and $\partial \Pr(d/p)/\partial\delta_m$ is that, as can be inferred from Proposition 2, higher volatility increases the cost of funds for domestic banks by

$$\frac{\partial \tilde{r}_b^f}{\partial \delta_m} = (\frac{C_b}{wn_h})\frac{\partial \Pr(d/b)}{\partial \delta_m},$$

whereas higher volatility does not affect the domestic banks' expected cost of funds on world capital markets (which is equal to the safe interest rate r_0^f). Adjusting for this effect, and assuming that the default repayment $\Phi(\cdot)$ is linear, it follows that

$$\frac{\partial \Pr(d/p)}{\partial \delta_m} = \frac{[1-\Pr(d/p)]^2 + (\frac{C_b}{\kappa B})\frac{\partial \Pr(d/b)}{\partial \delta_m}}{2\delta_m[1-\Pr(d/p)] - \frac{C}{\kappa B}},$$

implying that

$$C\frac{\partial \Pr(d/p)}{\partial \delta_m} + C_b\frac{\partial \Pr(d/b)}{\partial \delta_m} = C\frac{[1-\Pr(d/p)]^2 + (\frac{C_b}{\kappa B})\frac{\partial \Pr(d/b)}{\partial \delta_m}}{2\delta_m[1-\Pr(d/p)] - \frac{C}{\kappa B}} + C_b\frac{\partial \Pr(d/b)}{\partial \delta_m},$$

which can be rearranged to give

$$C\frac{[1-\Pr(d/p)]^2}{2\delta_m[1-\Pr(d/p)] - \frac{C}{\kappa B}} + C_b\Omega\frac{\partial \Pr(d/b)}{\partial \delta_m},$$

where Ω is defined, as in the text, by

$$\Omega = \frac{2\delta_m[1-\Pr(d/p)]}{2\delta_m[1-\Pr(d/p)] - \frac{C}{\kappa B}}.$$

Using (A5) this expression becomes

$$C\frac{1-\Pr(d/p)}{2\delta_m - \frac{C}{\kappa B[1-\Pr(d/p)]}} + C_b\Omega\frac{1-\Pr(d/b)}{2\delta_m - \frac{C_b}{\kappa_b B[1-\Pr(d/b)]}},$$

which can be substituted in (16) to give (17).

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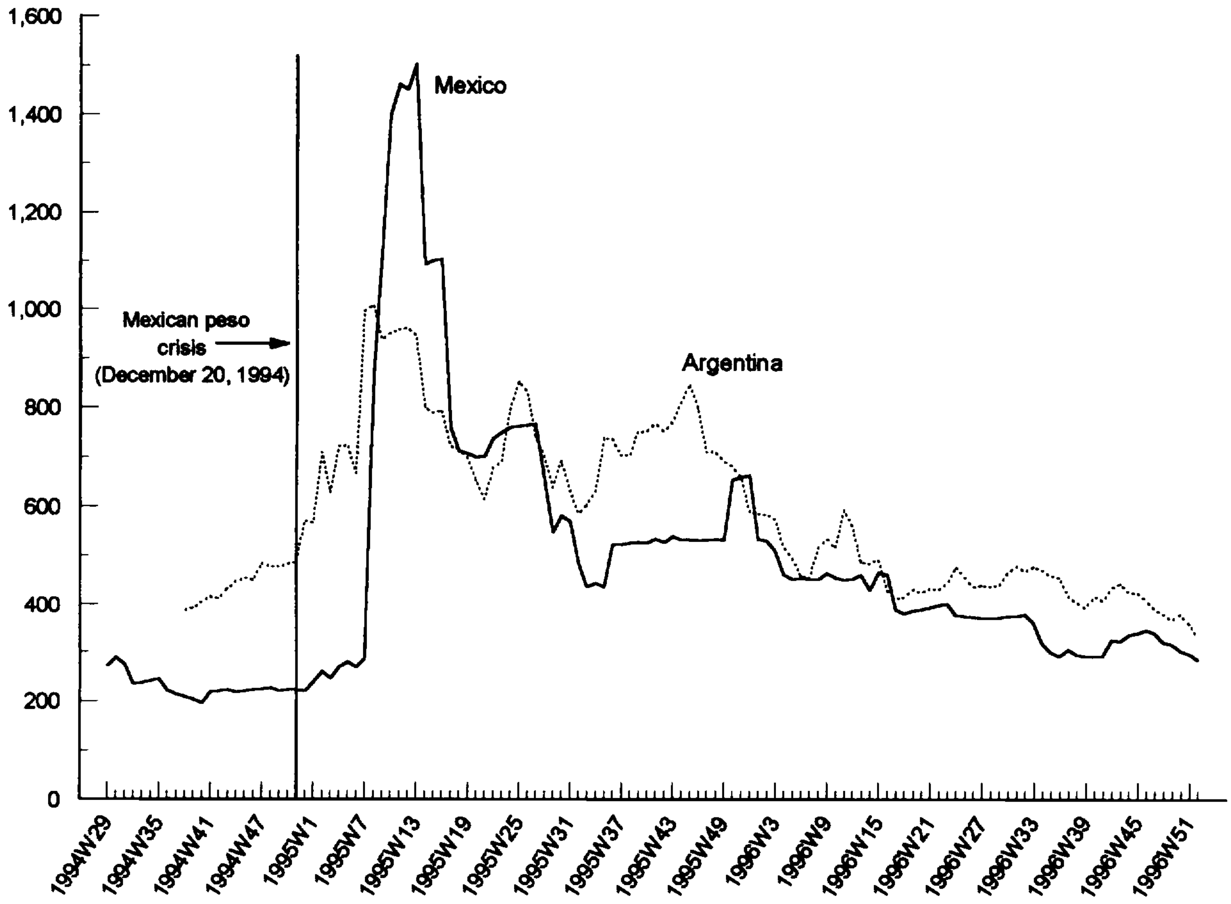
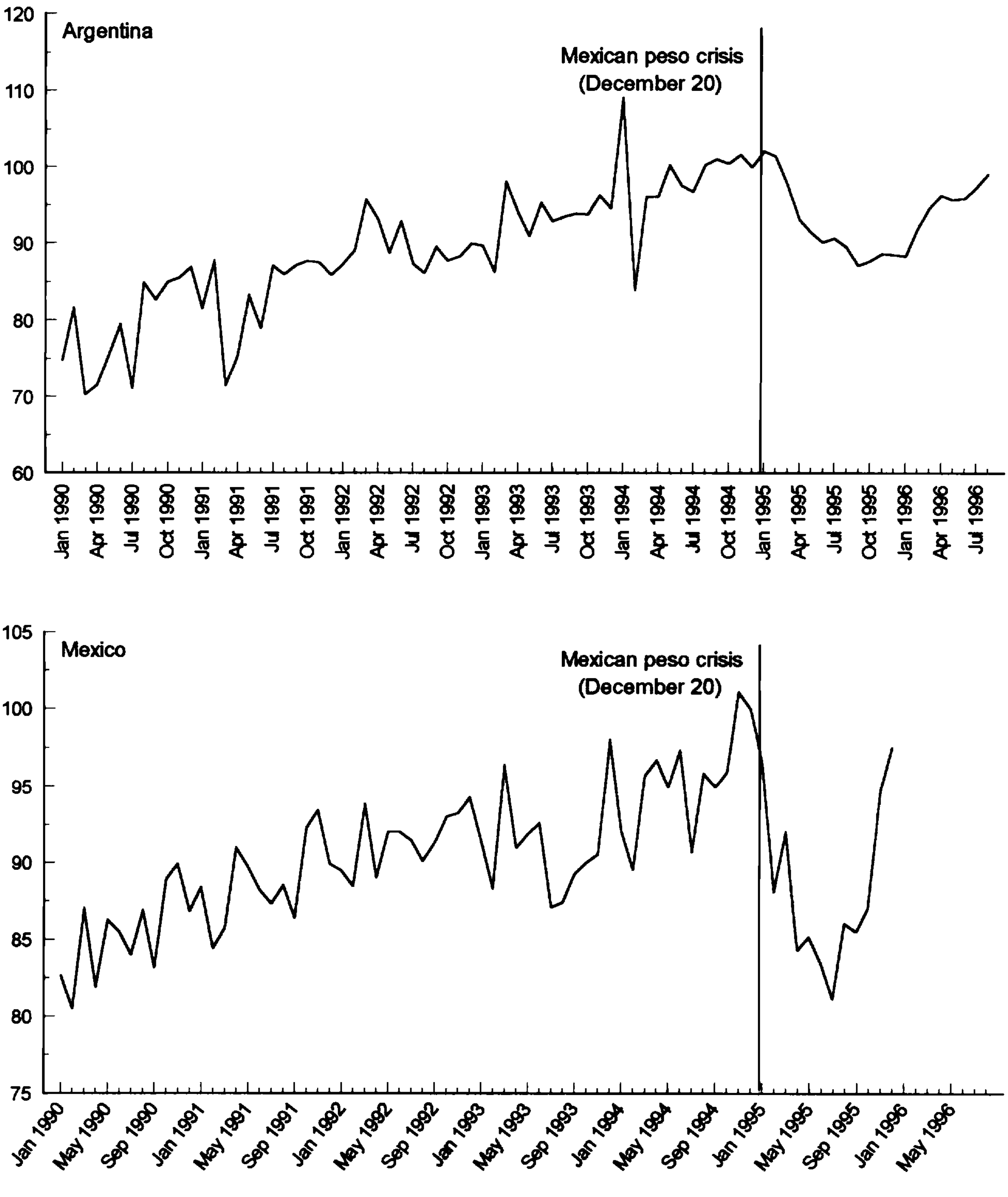
Figure 1
Argentina and Mexico: Secondary Market Yield Spreads
on U.S. Dollar-Denominated Eurobonds *
(In basis points)



Sources: Bloomberg and Reuters.

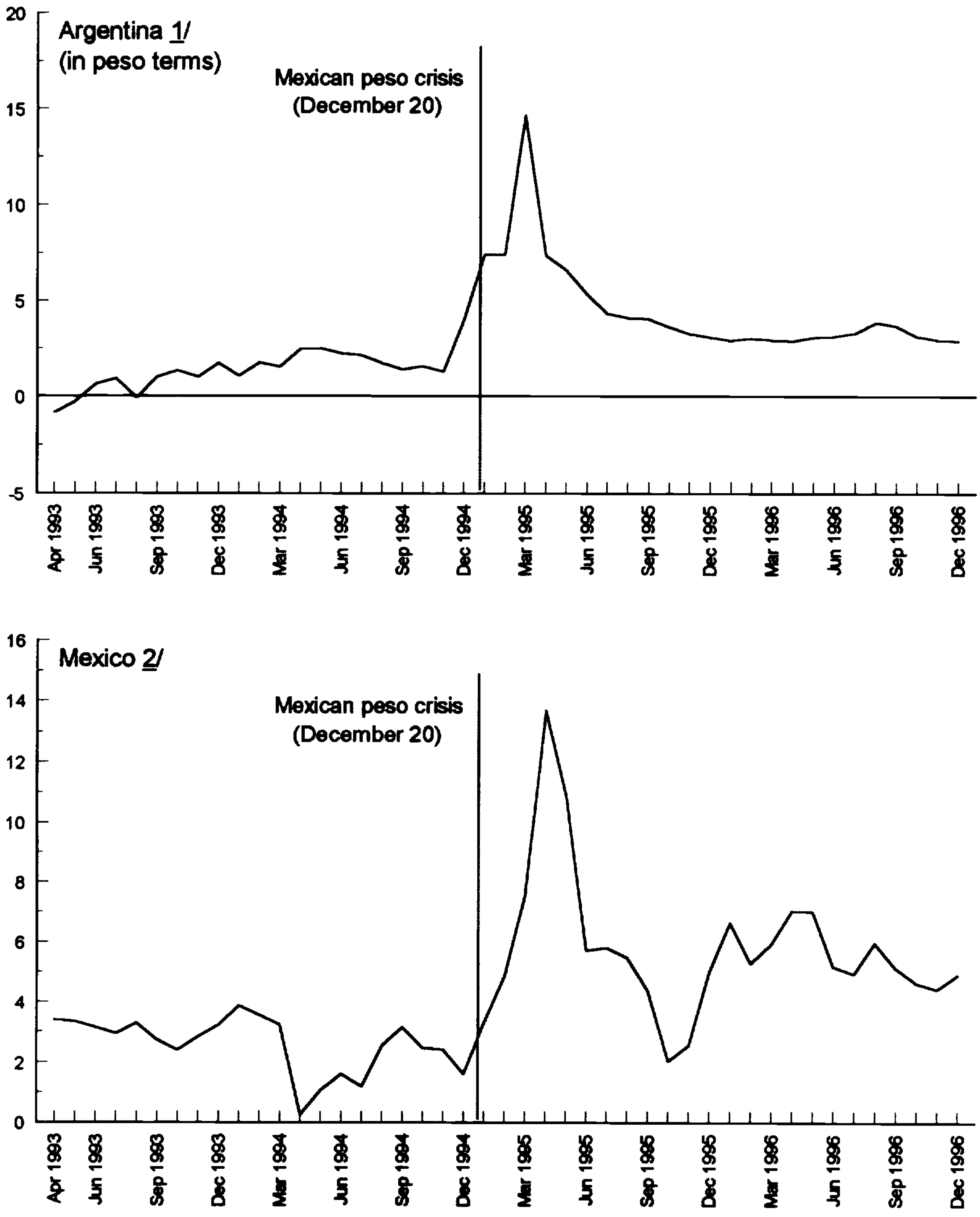
* Republic of Argentina bond due December 2003; United Mexican States bond due September 2002.

Figure 2
Argentina and Mexico: Industrial Output
(December 1994 = 100)



Sources: FIEL and IFS.

Figure 3
Argentina and Mexico: Domestic Interest Rate Spread



Sources: IFS.
1/ Lending rate minus deposit rate.
2/ Average cost of funds minus the deposit rate.

Figure 4

Determination of the Default Region

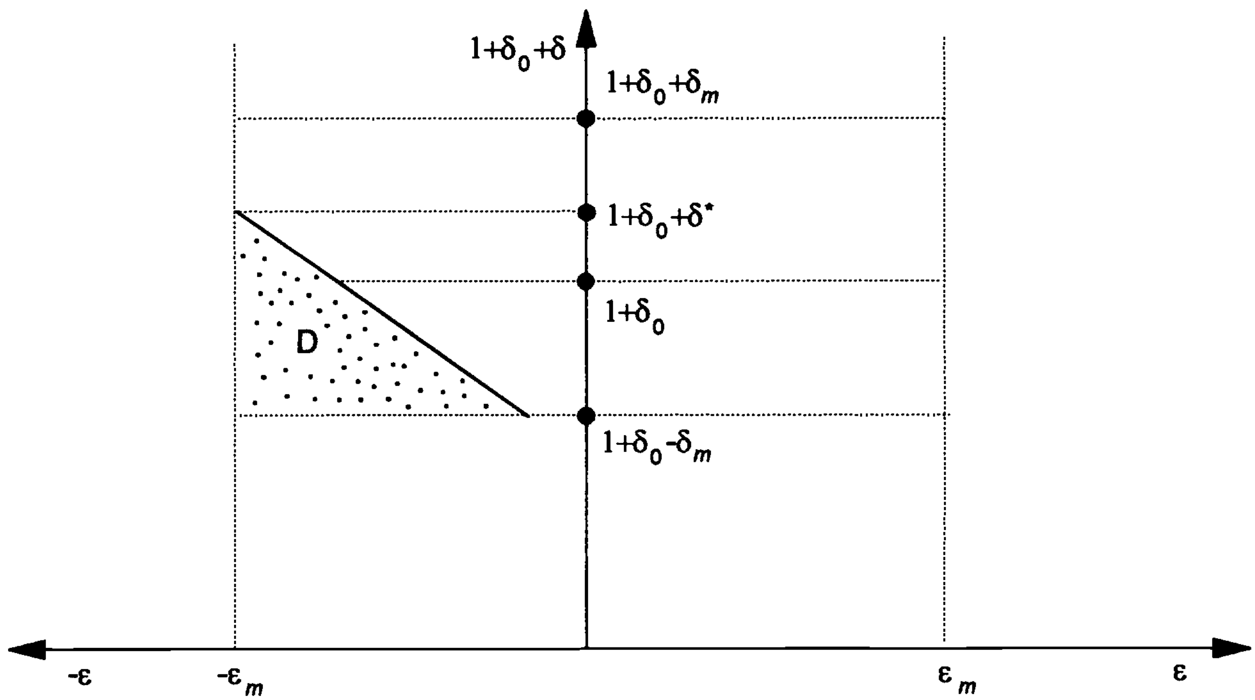
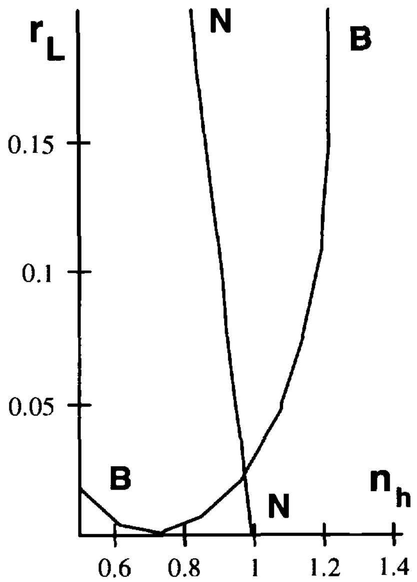


Figure 5

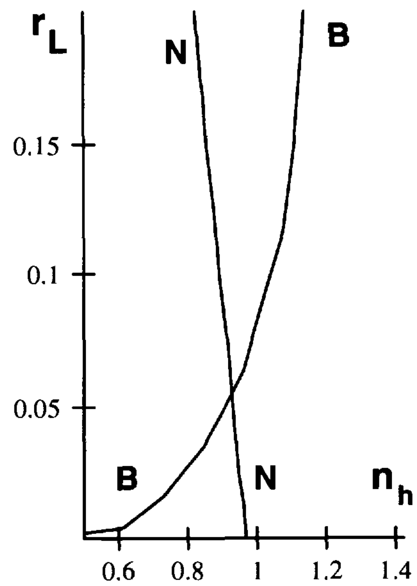
Optimal employment and domestic borrowers interest rate.

Simulated for $C=0.15,\ \ \beta=0.5,\ \ w=0.5,\ \ \tilde{r}_b^f=0,\ \ k=0.6$



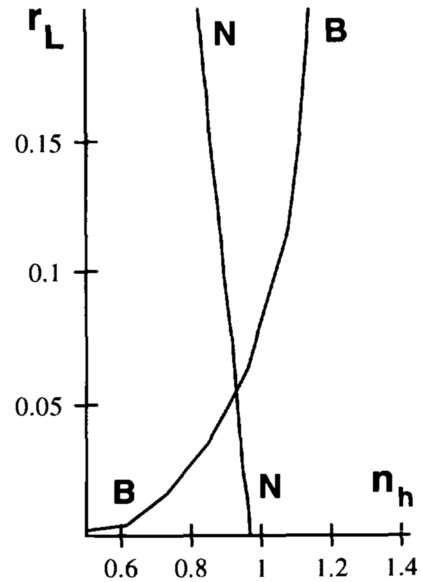
(1)

$\delta_m=\varepsilon_m=0.2,\ \ \delta_0=0.1.$



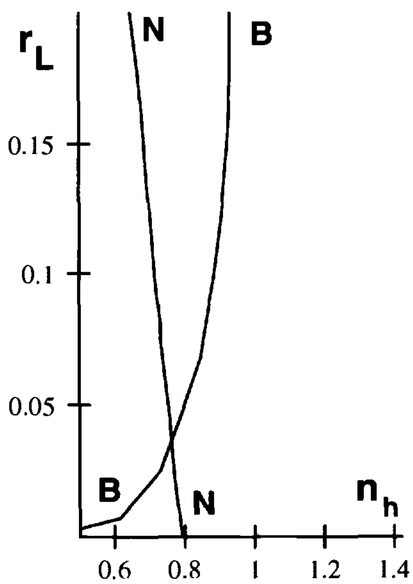
(2)

$\delta_m=0.2,\ \ \varepsilon_m=0.3,\ \ \delta_0=0.1.$



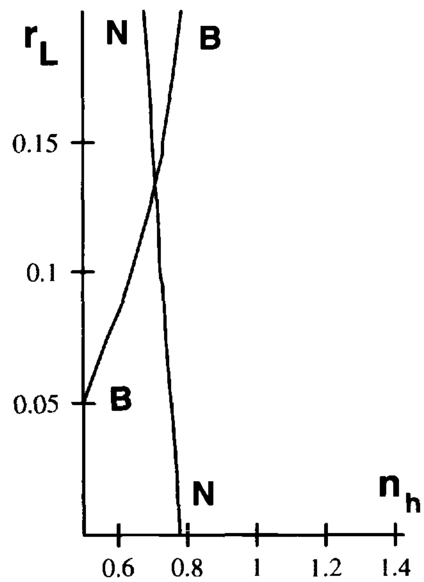
(3)

$\delta_m=0.3,\ \ \varepsilon_m=0.2,\ \ \delta_0=0.1.$



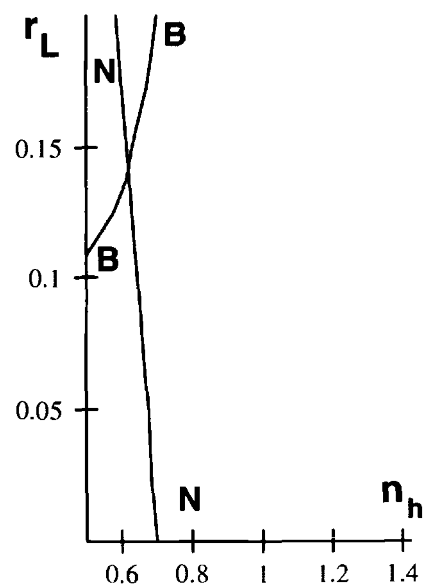
(4)

$\delta_m=\varepsilon_m=0.2, \delta_0=0$



(5)

$\delta_m=\varepsilon_m=0.3,\ \ \delta_0=0$



(6)

$\delta_m=\varepsilon_m=0.2, \delta_0=0.1,\ \tilde{r}_b^f=0.1$

Figure 6

Effect of an Increase in Volatility

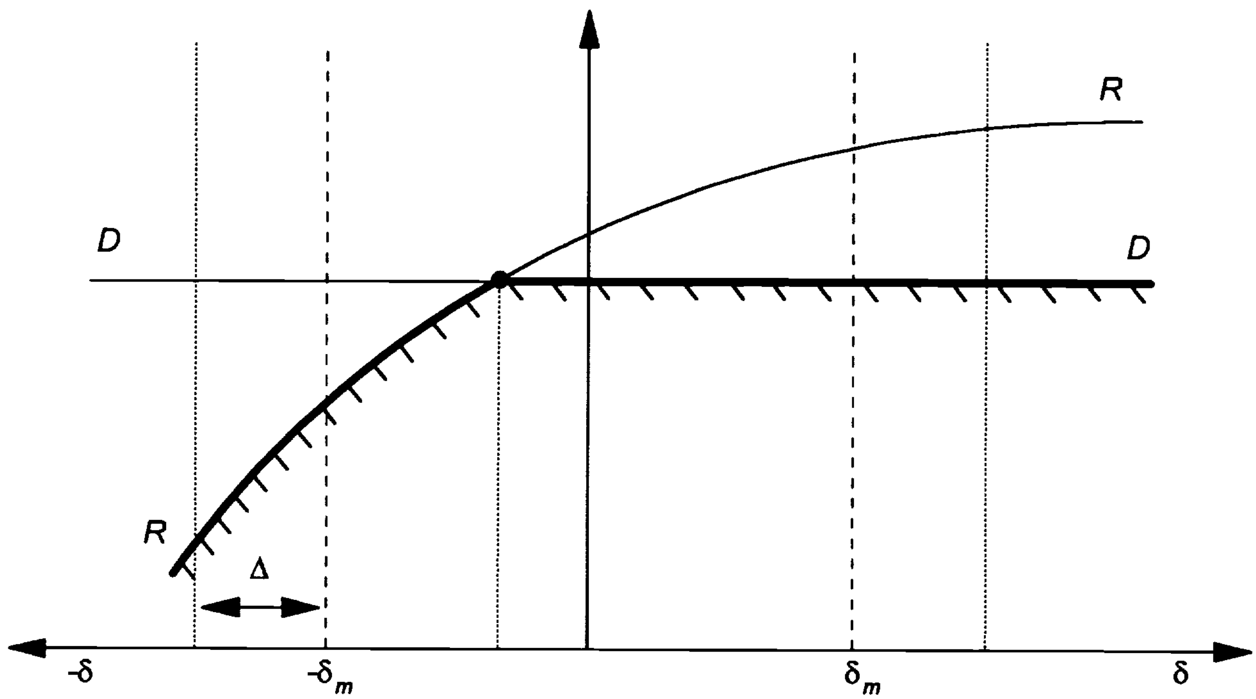


Figure 7

Volatility and the Expected Producers' Surplus