TIMOTHY J. KEHOE
Department of Economics, University of Minnesota

1. Can debt crises be prevented?*

Introduction

The financial crisis in Mexico in late 1994 and early 1995 came as a surprise to most observers, not so much because there was a major devaluation of the peso, but because the aftermath of this devaluation left the Mexican financial system and economy in a crisis from which it only in 1996, more than a year later, started to recover. The conventional wisdom, as presented by, for example, Dornbusch and Werner (1994), was that a devaluation was exactly what Mexico needed to spur exports and growth. Instead, the devaluation occurred more or less simultaneously with (and perhaps touched off) a debt crisis in which the Mexican government found itself unable to roll over its debt. Fears of a default of one sort or another totally paralyzed the economy in late December 1994 and January 1995. An explanation of the Mexican crisis that focuses on Mexico's government debt has a puzzling aspect, however: in 1994 Mexico had a very low ratio of government debt to national product by international standards (see Table 1).

Table 1. Debt/GDP percentages for selected countries

	1990	*1991*	*1992*	*1993*	*1994*
Mexico	55.2	45.8	35.1	35.0	37.4
Belgium	130.7	132.6	134.4	141.3	140.1
France	40.4	41.1	45.6	52.9	56.8
Germany	43.4	42.7	47.3	51.8	54.6
Greece	77.7	81.7	88.6	117.1	119.8
Italy	100.5	103.9	111.4	120.2	122.6
Spain	48.7	49.9	53.0	59.4	63.5

Source: International Monetary Fund and Organization for Economic Cooperation and Development.

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This paper traces the events in 1994 that left Mexico vulnerable to a debt crisis – the steady conversion of government debt into short-term, dollar-indexed *tesobonos*. This conversion seems to have been the result of an agreement, both implicit and explicit, between the Mexican government and members of the international financial community.

The paper also proposes a theoretical framework, based on a model developed by Cole and Kehoe (1996b), for identifying situations in which a debt crisis can occur. The essential feature of this framework is that there is an interval of levels of government debt, called the crisis zone, which depends heavily on the maturity structure of the debt, for which a crisis can occur. Furthermore, the framework formalizes the idea of 'herd behavior' of investors often discussed in the popular press: investors feared that Mexico would be unable to honor its commitments on government bonds becoming due. This made these investors unwilling to purchase new bonds. Since these fears were widespread, Mexico was unable to sell new bonds and, consequently, was in a position where default of some sort seemed inevitable. This situation then justified the expectations that Mexico would be unable to honor its commitments. Had these expectations not been present, however, no crisis would have occurred.

This theoretical framework suggests an accounting methodology for calculating the size of the crisis zone. Identifying situations in which debt crises can occur potentially goes a long way towards eliminating the possibility of such a crisis, since governments would then face strong pressures from financial markets to stay out of the crisis zone. The theoretical framework also suggests a significant potential role for an international lender of last resort which would sharply limit the possibility of debt crises in a manner similar to that in which a central bank can limit the possibility of runs on private domestic banks. As recent banking crises in such countries as Japan and the USA have illustrated, however, it is essential that a central bank serve as regulator as well as lender of last resort. Similarly, any international agency that would serve as lender of last resort should be willing to provide this service only at the price of being able to regulate government financial policy.

Overview of the Mexican financial crisis

What went wrong in Mexico in 1994 was a combination of an unprecedented sequence of shocks to the Mexican political and economic system together with government policies that treated these shocks as transitory. It is easy now to identify these policies as errors. If a less adverse sequence of political and economic shocks had buffeted Mexico in 1994, however, these policies would probably now be regarded as successes.

In 1994, faced with political instability, a dramatic increase in short-term US interest rates, upcoming elections, a fragile domestic banking sector, and plummeting foreign portfolio investment, the administration of President

Carlos Salinas de Gortari made two decisions that resulted in the financial crisis: first, it allowed the Mexican peso only a small devaluation (a nominal 12%) against the US dollar over the course of the year, and in maintaining the value of the peso, without adjusting its monetary policy, it lost most of Mexico's foreign reserves. Second, as the Salinas administration refinanced Mexico's government debt during 1994, it allowed the debt to become mostly short-term and dollar-indexed.

The combination of these two decisions left Mexico open to a speculative attack, when investors realized that the Banco de México did not have enough reserves to continue supporting the peso, and shortly afterwards, a 'bank run', when bond holders realized that the Banco de México did not have enough reserves to meet the payments becoming due on the dollar-indexed debt.

In 1994, as it had in 1992 and 1993, Mexico ran a large current account deficit. What changed in 1994 was the level of foreign portfolio investment (Figure 1). 1994 was a difficult year politically for Mexico: there was an uprising in Chiapas in January; the presidential candidate of the ruling *Partido Revolucionario Institutional* (PRI), Luis Donaldo Colosio Murrieta, was assassinated in March; the Secretary of the Interior, Jorge Carpizo McGregor, who had been encharged with ensuring honest elections in August, threatened to resign in June; the Secretary General of the PRI, Jose Francisco Ruiz Massieu, was assassinated in September; Ruiz Massieu's brother Mario resigned as assistant attorney general in November, charging a high-level coverup of the

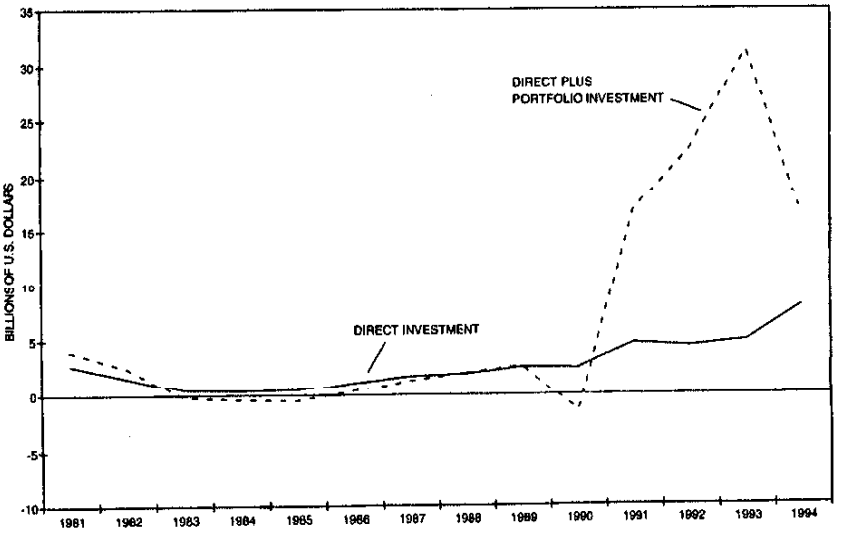

Figure 1. Foreign investment in Mexico.
Source: IMF, *Balance of Payments Statistical Yearbook*, various issues.

assassination within the PRI; and there were threats of new uprisings in Chiapas in November and December.

The political uncertainty generated by these events, combined with rising interest rates that made the USA a more attractive investment target, resulted in a substantial drop in foreign investment: foreign portfolio investment in Mexico fell from US$ 28.4 billion in 1993 to US$ 8.2 billion in 1994. (It is worth noting, however, that foreign direct investment actually rose from US$ 4.9 billion to US$ 8.0 billion.)

Perhaps even more significantly, there were presidential elections in August, with the new president, Ernesto Zedillo Ponce de León who had replaced Colosio as the PRI candidate, taking office in December. The change of government was, as it has been every 6 years in Mexico since 1928, a time of great uncertainty. At the end of each of the previous three administrations – in 1976, 1982, and in 1987 – there had been large devaluations. Mexicans and foreign investors had come to associate ends of presidential terms with devaluations.

In the face of the drop in foreign investment, the Salinas administration continued to maintain the value of the peso against the dollar. There were good reasons to do so, at least during the first half of 1994. A series of social pacts negotiated between leaders of government, business, and labor had, since 1987, set a policy of a maximum allowable rate of depreciation of the peso against the dollar. This policy had resulted in a decline in the rate of inflation in Mexico from 159.2% in 1987 to 7.1% in 1994. At the same time real wages, which had fallen sharply following the 1982 financial crisis, rose by more than 20% between 1987 and 1994.

To the extent to which the Salinas administration believed that the shocks that buffeted Mexico in 1994 were transitory, it was justified in selling the Banco de México's foreign reserves to insulate Mexico from these shocks. At the same time that Mexicans and foreigners were selling pesos for dollars, the Banco de México was sterilizing by reissuing the pesos. This policy was designed to promote a stable money supply and interest rates. With elections due in August, it is easy to understand why these sorts of policies were attractive during the first three-quarters of 1994.

Policy judgements often involve calculated risks, and poor judgements are far easier to identify if there is a run of bad luck than if there is not. As political shocks continued to hit Mexico during the fall of 1994, foreign reserves fell to dangerously low levels. November was a crucial month: it was in November that foreign reserves fell below the Mexican monetary base, and on November 18 alone the Banco de México had to sell US$ 1.7 billion to maintain the value of the peso.

Monetary policy and the loss of reserves

Figure 2 traces out the behavior of foreign reserves held by the Banco de México during 1994. It is worth noting that the Banco de México made

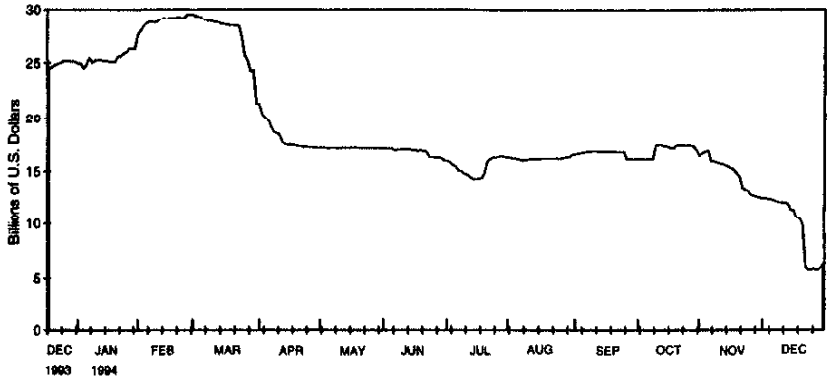

Figure 2. Mexican international reserves. December 1993–December 1994*.

* Daily data.

Source: Mancera, *Wall Street Journal*, 31 January 1995.

significant interventions in the peso/dollar markets only during six, relatively brief periods: 19 January–11 February, following Mexico's entry into NAFTA, when despite the uprising in Chiapas, the Banco de México had to buy US$ 4.2 billion to keep the value of the peso down; 25 March–21 April, following the Colosio assassination, when it had to sell US$ 10.4 billion to keep the value of the peso up; 23 June–12 July, during the uncertainty over the Carpizo resignation, when it sold US$ 2.7 billion; 14–23 November, during Mario Ruiz Massieu's allegations of a coverup of his brother's assassination, when it sold US$ 3.6 billion; 15–19 December, during threats of a new uprising in Chiapas, when it sold US$ 1.8 billion; and 20–21 December, during the first stage of the devaluation, when it sold US$ 4.6 billion. During these six periods the Banco de México intervened on a total of 53 days. During all of the rest of 1994 the Banco de México only intervened on 18 days, selling a total of US$ 1.2 billion. (All of these data are taken from Banco de México, 1995.)

Figure 3 illustrates the response of monetary policy to the decline in reserves: the Banco de México sterilized, in January and February, by contracting domestic credit to keep the money supply down as it sold pesos for dollars, and, later, by expanding domestic credit to keep the money supply up as it bought pesos with dollars. This policy helped insulate the Mexican domestic economy, in particular the banking industry, from a sharp decline in the money supply that would have otherwise resulted from the drop in foreign portfolio investment. In 1994, the Mexican banking industry, which had expanded rapidly following its privatization in 1991, was in fragile condition: non-performing loans had risen from 2.3% of total loans in 1990 to 9.5% by the end of 1994.

One way in which the Banco de México expanded domestic credit during 1994 was through loans to the seven national development banks, pricipally, Nacional Financiera (NAFIN), which makes loans to small- and medium-sized

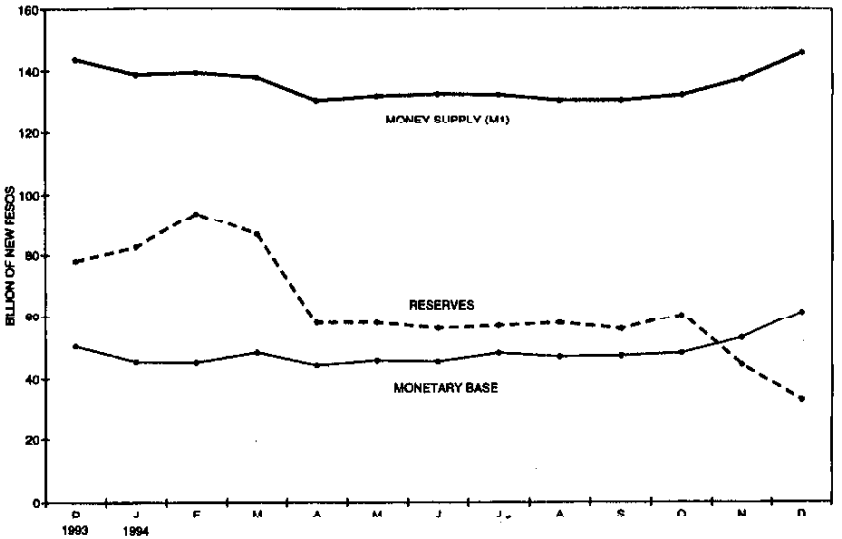

Figure 3. Mexican international reserves vs. money supply. December 1993–December 1994. Source: Secretaría de Hacienda y Crédito Público.

enterprises; Banco Nacional de Comercio Exterior (BANCOMEXT), which finances foreign trade activities; and Banco Nacional de Obras y Servicios Públicos (BANCOBRAS), which finances state and municipal projects. Between 1992 and 1994 the development banks' credit outstanding rose from 2.5% of Mexican GDP to 4.0%.

In retrospect, Mexican monetary policy during 1994 can be viewed as a calculated gamble: the Salinas administration reacted to the shocks that led to falls in foreign portfolio investment as though each shock was the last that would occur. In particular, it ran down foreign reserves in an effort to keep both the exchange rate and the domestic money supply constant. Unfortunately, the shocks kept occuring and, absent a sharp tightening of monetary policy in the fall of 1994, Mexico was eventually forced to let the peso devalue.

Debt management and the debt crisis

Mexican government debt can be divided into two broad categories: domestic and external. This division has nothing to do with who holds the debt; rather it depends on where it is sold. Domestic debt is sold at auctions held by the Banco de México, while external debt is sold abroad. The debt crisis was caused by a run on domestic debt. Although yields on such external debt instruments as Brady bonds increased sharply on secondary markets during the crisis, Mexican external debt has a long maturity structure. The immediate

danger of default was the result of the short maturity structure of the domestic debt.

Table 2 traces the evolution of composition of Mexican domestic government debt during 1994. There were four types of debt instruments: *certificados de la tesorería de la federación (cetes)*, peso-denominated bonds with maturities of 28, 91, 182, 364, and 728 days; *tesobonos*, dollar-indexed bonds with maturities of 91, 182, and 364 days; *bonos de desarrollo (bondes)*, peso-denominated bonds with maturities of 1, 2, and 10 years; and *ajustabonos*, inflation-indexed, peso-denominated bonds with maturities of 3 and 5 years.

Following the assassination of Colosio in March, the Mexican government steadily converted its domestic debt from peso-denominated *cetes*, *bondes* and *ajustabonos* into dollar-indexed *tesobonos*, as depicted in Figure 4. In the second week of March 1994, due to uncertainty about the situation in Chiapas and a possible independent presidential campaign by Manuel Camacho Solís, who had been edged out as the PRI candidate by Colosio, the peso had begun to fall against the dollar. The assassination accelerated this fall, and the peso moved from the bottom to the top of its trading band, devaluing by almost 8% over a month. This drop in the value of the peso led to a sharp increase in Mexican interest rates with a resulting drop in the prices of Mexican bonds and equities. According to Torres and Vogel (1994), much of this movement into *tesobonos* was the result of discussions between representations of the Weston Forum, a group of New York investment funds, and officials of the Mexican Finance Secretariat and the Banco de México.

To understand the importance of the move of Mexican debt into *tesobonos*, it is worth understanding how these bonds worked. *Tesobonos* were sold by the Banco de México in weekly auctions. The Banco received bids in US

Table 2. Outstanding domestic government debt in Mexico 1994 (billion $US)*

Month	*Cetes*	*Tesobonos*	*Bondes*	*Ajustabonos*	*Total*
January	24.07	2.43	5.22	10.82	42.54
February	26.68	2.57	5.35	10.63	45.23
March	22.04	4.10	4.07	9.64	39.85
April	13.06	10.15	2.19	8.64	34.04
May	13.61	11.94	2.11	8.23	35.89
June	12.47	12.99	2.32	7.69	35.47
July	10.34	16.40	2.04	6.83	35.61
August	9.40	19.47	1.36	6.24	36.47
September	9.13	18.69	2.00	5.94	35.78
October	9.35	17.55	1.82	5.46	34.18
November	7.34	18.62	1.14	5.22	32.32
December	3.94	21.55	0.58	3.31	29.38

Source: Banco de México (1995) and International Monteary Fund, *International Financial Statistics*, various issues.

* Market values converted to $US (in the case of *cetes*, *bondes* and *ajustabonos*) using the exchange rate at the end of the month.

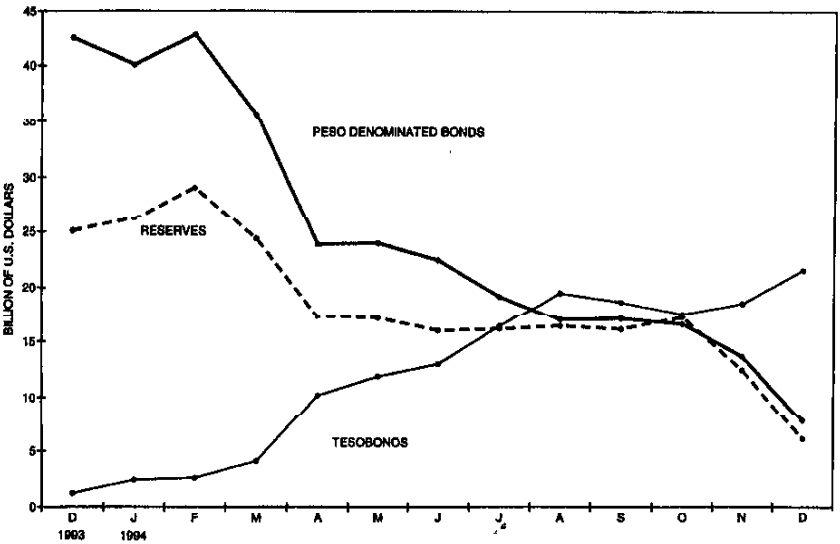

Figure 4. Mexican international reserves vs. Government bonds. December 1993–December 1994. Source: Secretaría de Hacienda y Crédito Público.

dollars at 9:30 am on Tuesdays. An 11:00 am fix of the peso–dollar exchange rate determined the peso value of those bids. On Thursdays payments and deliveries were made. *Tesobonos* were sold in maturities that were multiples of 7 days, but most were 91-day bonds. The weekly calendar for settlements was the same as that for sales: the peso value of maturity debt was determined by the 11:00 am Tuesday fix, and payments were made on Thursdays.

The movement away from peso-denominated debt into dollar-indexed debt helped to shield debt holders from exchange rate risk. It also allowed the Mexican government to borrow at substantially lower interest rates, as shown in Figure 5. The movement in the composition of the debt had two adverse effects on Mexican government finances, however: it exposed the government to far more exchange rate risk, and it sharply reduced the already short maturity structure of the debt (see Table 3).

Following the 20–22 December devaluation, rumors abounded that the Mexican government would impose dual exchange rates, paying off *tesobonos* at an official rate lower than the market rate. It did not take too long a memory to recall that the Mexican government had resorted to similar policies during the 1982 financial crisis. The *tesobono* auctions of 27 December, 3 January and 10 January were complete failures: the Banco de México was able to sell only US$ 143 million worth of bonds out of US$ 1.5 billion offered.

In retrospect, it is difficult to rationalize Mexican debt management during 1994. The policy of converting peso-dominated debt into dollar-indexed debt exposed the Mexican government to substantial exchange rate risk. This policy

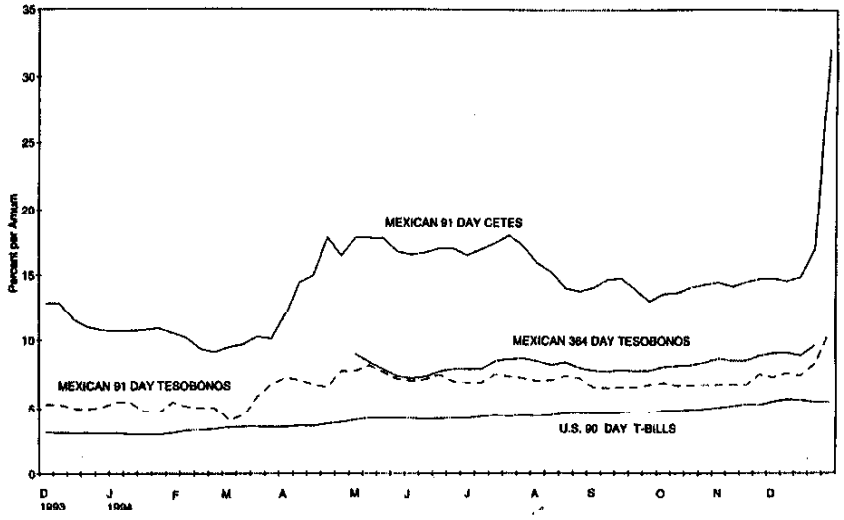

Figure 5. Interest rates Mexican–US Government bonds. December 1993–December 1994. Source: Bloomberg Financial Market.

Table 3. Average maturity of domestic government debt in Mexico 1994 (days)

Month	*Cetes*	*Tesobonos*	*Bondes*	*Ajustabonos*	*Average**
January	161.1	72.5	317.6	740.8	322.7
February	168.7	82.1	317.5	772.5	323.3
March	164.3	87.5	299.8	809.6	326.3
April	150.3	71.6	266.8	856.9	313.7
May	155.2	125.1	248.0	865.9	313.6
June	156.7	120.5	208.8	878.4	303.3
July	158.8	136.4	213.4	880.6	290.1
August	156.7	155.9	249.9	896.8	286.4
September	149.4	155.8	171.0	881.2	275.4
October	146.0	166.5	172.1	837.7	268.4
November	144.3	158.2	191.9	838.9	266.2
December	147.0	138.4	176.0	841.3	219.5

Source: Secretaría de Hacienda y Crédito Público.
* Weighted average using weights from Table 2.

made sense only if the Mexican government had private information that the risk of devaluation was lower than financial markets thought that it was. The sale of *tesobonos* demonstrated a confidence on the part of the government that later events proved unjustified and that, in any case, financial markets did not share.

Modeling self-fulfilling debt crises

Cole and Kehoe (1996b) present a formal model that captures the intuition that the Mexican debt crisis was self-fulfilling in the sense that the failure of the government's auctions of new debt put the government into a position where default seemed inevitable, thereby justifying the panic that led to the failure of the auctions. This model and relevant results are described in the appendix

The model has three types of actors: domestic consumers, who make consumption and investment decisions; foreign investors, who purchase government debt and are risk neutral, reflecting the small size of the country relative to world capital markets; and a government, which taxes, spends on public goods, offers new bonds for sale, and decides whether or not to honor commitments on old bonds. The central actor in the model is the government. Cole and Kehoe (1996b) model the government as benevolent in that it seeks to maximize the welfare of the domestic consumers; they show, however, how it is also possible to model the government as more impatient than consumers or international investors. The welfare of consumers and governments depends both on private consumption and on provision of the public good.

The government cannot commit to repaying its debt; all of the actors know that the government resolves its maximization problem every period. If the expected present value of defaulting exceeds that of repaying old debt, the government will default. If the government defaults, the country is subject to a penalty that results in a decline in domestic productivity. This penalty reflects, for example, the large distortion created by the imposition of dual exchange rates. In the model, for some levels of government debt, a crisis can occur depending on the realization of a random event that is extrinsic to the fundamentals of the model, a sunspot variable. An unfavorable realization of this sunspot variable can lead to a panic in which the international investors are unwilling to purchase new government debt. This panic is rational if the failure of the new debt auction puts the government in a situation where it prefers to default. At the same time, however, the panic is somewhat arbitrary because a favorable realization of the sunspot variable would not lead to a panic, the government would be able to sell its new debt, and no crisis would occur.

In this model a self-fulfilling crisis is possible if the government would choose to default if no new borrowing were possible, but would choose to honor its commitments if new borrowing were possible. Cole and Kehoe (1996b) show that, if a crisis is possible, the probability of its occurence is arbitrary: for any probability of an unfavorable realization of the sunspot variable, there is a different equilibrium. Although Cole and Kehoe model the crisis as dependent on a sunspot variable, it is also possible to model it as dependent on a random event connected to the fundamentals, such as a political shock. The essential point is that there are multiple equilibria: there is an equilibrium in which the shock touches off a crisis and there is an equilibrium in which it does not.

The crucial insight of the model is that the government finds itself in a far different position if it cannot sell its new bonds than if it can. If the level of government debt is low compared with its ability to raise revenue, however, these positions are not very different: the government will choose to repay its debt and to avoid the default penalty whether or not new borrowing is possible. Similarly, if the maturity structure of the debt is long enough, these positions are not very different: with government debt of long maturity little new borrowing is needed in any one period. Figure 6 depicts the size of the crisis zone for a simple model described in the appendix that has been calibrated to match the general features of the Mexican economy in 1994. For levels of the debt too high, a crisis occurs immediately; for low levels of the debt, no crisis is possible; and, for intermediate levels of the debt – levels in the crisis zone – a crisis can occur with fairly arbitrary probability. Notice how fast the crisis zone shrinks as the maturity of the debt increases. For a variety of reasons not explained by the model, bonds with a short maturity may be less risky than those with a long maturity if the maturity structure itself is constant. Nevertheless, one lesson that can be drawn from the model, a lesson that financial markets did not seem to understand in 1994, is that letting the whole maturity structure shorten is very risky.

Although the Cole–Kehoe model is only a simple first step at modeling events like the Mexican financial crisis, it provides a framework that may eventually be capable of identifying countries in danger of a crisis like that which hit Mexico in 1994–95. A country is in danger of a crisis if the amount

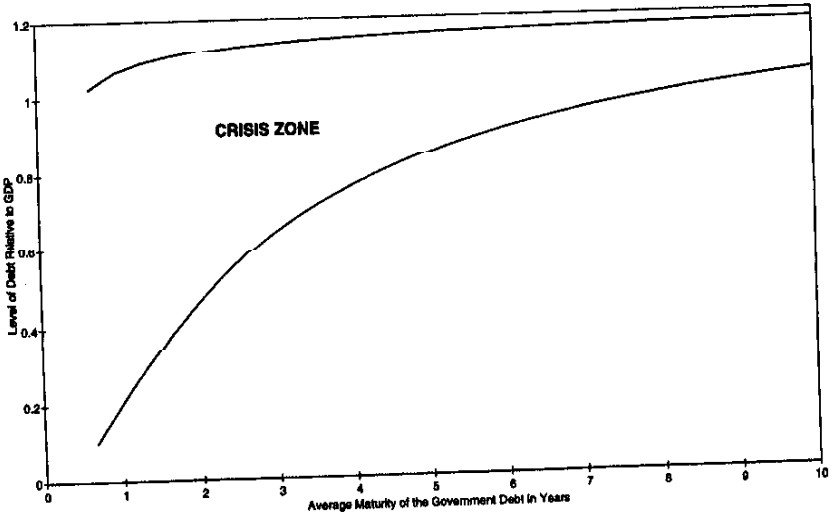

Figure 6. Average maturity of the debt and the crisis zone.

of government debt becoming due during, say, one quarter is large compared with its ability to raise taxes or to cut expenditures and compared to its foreign reserves. It is worth noting that a government might find itself in danger of a self-fulfilling debt crisis even though it would have no problem meeting the interest payments on its debt, or even in eventually reducing this debt to a level below the crisis zone. In terms of the literature on bank runs, the government may be illiquid even though it is solvent.

An international lender of last resort?

The first step towards resolving the Mexican debt crisis was taken on 31 January 1995, when US President Bill Clinton announced a US$ 48.8 billion loan package put together primarily by the US Exchange Rate Stabilization Fund, the International Monetary Fund, and the Bank for International Settlements. It was not until 9 March, however, that the Zedillo administration was able to put together a complete economic plan for the year. Essential features of the economic program enacted in Mexico during January–March included a rapid opening of the banking sector to foreign competition and foreign ownership, an increase in taxes, and measures to aid domestic banks left in precarious positions by the devaluation. In general, the period from late December through early March was a period of great uncertainty and economic paralysis in Mexico.

It is plausible that most of the uncertainty and paralysis that afflicted Mexico in early 1995 could have been eliminated if the loan package had been made available, say, a month earlier. This has led commentators like Eichengreen and Portes (1995) and Sachs (1995) to propose international institutional mechanisms for dealing with crises like that in Mexico. An international lender of last resort conceivably would have prevented the run on Mexican government debt and allowed the Mexican economy to recover very quickly after the December devaluation.

A crucial question, of course is, When does a lender of last resort lend? It is one thing to lend to support a budget deficit or to support an exchange rate that is subject to repeated speculative attacks. It is another thing to lend to stop a run on government debt. Much the same as Bagehot (1873) proposed a lender of last resort to eliminate domestic bank runs, an international lender of last resort could, by its very existence, eliminate the possibility of a crisis like the Mexican crisis: international investors, knowing that the government has access to an international lender of last resort, would not find it rational to panic. As shown in the appendix, an international lender of last resort can eliminate the possibility of a crisis in the Cole–Kehoe model.

It is worth recalling Bagehot's conditions for a central bank to provide credit to an illiquid domestic bank: the domestic bank should be solvent; it should provide good collateral; and there should be a penalty interest rate. All

of these three features were present in the Mexican crisis and its subsequent resolution: the debt service on Mexican government debt was very small in relation to Mexican government revenue; the Mexican government was able to use its oil export revenues as collateral; and the loan package involved substantially higher interest rates than those the Mexican government was paying before the crisis. (See US General Accounting Office 1996 for details on the agreements.)

The concept of international lender of last resort is one deserving more attention. It is worth making two related observations, however: First, serving as lender of last resort without regulating creates a potential moral hazard problem. Governments will undertake riskier policies if they know that an international lender of last resort stands ready to bail them out. Second, an international lender of last resort indirectly inherits much of the responsibilities of the domestic central bank in serving as lender of last resort to domestic commercial banks. A country like Mexico in 1994 and 1995, with a fragile domestic banking system, will use its monetary and debt management policies to insulate these banks from unfavorable shocks. To properly regulate a central bank, an international lender of last resort needs to make sure that the central bank is properly regulating domestic commercial banks.

Appendix

The Model

This section lays out the model utilized by Cole and Kehoe (1996b) to analyze the 1994–95 Mexican debt crisis. There is a single good in each period, $t = 0, 1, \ldots$. This good can either be consumed or be saved as capital. Production utilizes capital and implicitly, inelastically supplied labor. There are three types of people in the model: domestic consumers, international investors, and the government. We describe each in turn.

There is a continuum with measure one of identical, infinitely lived domestic consumers. The consumers' utility function is

$$E \sum_{t=0}^{\infty} \beta^t (c_t + v(g_t))$$

where c_t is private consumption and g_t is government consumption. We assume that $0 < \beta < 1$ and that v is continuously differentiable, concave, and monotonically increasing. The consumer's budget constraint is

$$c_t + k_{t+1} - k_t \leq (1 - \theta)(\alpha_t f(k_t) - \delta k_t).$$

Here α_t is a productivity factor that depends on whether or not the government has ever defaulted; δ, $0 \leq \delta \leq 1$, is the depreciation factor; θ, $0 < \theta < 1$, is the constant proportional tax on domestic income; and f is a continuously

differentiable, concave, and monotonically increasing production function. Each consumer is endowed with k_0 units of capital in period 0.

Cole and Kehoe (1996a) explore a model in which domestic consumers have a more general, concave utility of consumption and in which they can borrow from, and lend to, the international investors. The assumption of risk neutrality of consumers greatly simplifies the modeling of consumer behavior. For example, it allows us to neglect the possibility of borrowing and lending without loss of generality.

There is also a continuum with measure one of identical, infinitely lived international investors. These investors are risk neutral and have the utility function

$$E \sum_{t=0}^{\infty} \beta^t x_t.$$

The assumption of risk neutrality of investors captures the idea that the domestic economy is small compared to world financial markets. Each investor is endowed with $\bar{x}$ units of the consumption good in each period and faces the budget constraint

$$x_t + q_t b_{t+1} \leq \bar{x} + z_t b_t.$$

Here q_t is the price paid for one-period government bonds that pay b_{t+1} in period $t+1$ if $z_{t+1} = 1$, but pay 0 if $z_{t+1} = 0$; $z_t \in (0, 1)$ is the government's default decision. We can choose the endowment $\bar{x}$ to be large enough that we can ignore corner solutions to the investor's utility maximization problem. Initially, each investor holds b_0 units of government debt. There is a constraint $b_{t+1} \geq -A$, where A can be chosen large enough so that it rules out Ponzi schemes but does not otherwise bind in equilibrium.

There is a single government. In every period it chooses its new borrowing level, B_{t+1}; whether or not to default on its old debt, z_t; and the level of government consumption, g_t. If the government defaults by setting $z_t = 0$, then productivity drops from $\alpha_t = 1$ to $\alpha_t = \alpha < 1$ from period t onward. In period 0, the government debt is $B_0 = b_0$.

The government is benevolent in that its objective is to maximize the welfare of domestic consumers. Its budget constraint is

$$g_t + z_t B_t \leq \theta(\alpha_t f(k_t) - \delta k_t) + q_t B_{t+1}.$$

We do not need to impose a borrowing constraint on the government to rule out Ponzi schemes because, if the government tries to sell too much new debt B_{t+1}, the price q_t falls to zero. That the tax rate is constant captures the idea that changes in tax policy occur much more slowly than do debt crises.

In each period there is an exogenous sunspot variable ζ_t, whose value is realized. This variable is independently distributed on the interval $[0, 1]$. In the next section we describe equilibria where, if the level of government debt B_t is above some crucial level and ζ_t is below another crucial level, then international investors are not willing to buy new government debt and the

price of this debt is $q_t = 0$. This unwillingness to buy government debt creates a self-fulfilling debt crisis in the sense that, since the government cannot sell new debt, it chooses to default. If ζ_t is above the crucial level, however, international investors lend to the government and no default occurs. The possibility of a debt crisis depends on the level of government debt: if B_t is below the crucial level, then investors know that the government will not default, whether or not they buy the new debt; they therefore buy the new debt.

The timing of actions within each period is important to the presentation of the model:

- ζ_t is realized, and the aggregate state is $s_t = (B_t, K_t, \alpha_{t-1}, \zeta_t)$.
- The government, taking the price schedule $q_t = q(s_t, B_{t+1})$ as given, chooses B_{t+1}.
- The international investors, taking q_t as given, choose whether to purchase B_{t+1}.
- The government chooses whether or not to default, z_t, and how much to consume, g_t.
- The consumers, taking α_t as given, choose c_t and k_{t+1}; in equilibrium $k_{t+1} = K_{t+1}$.

The essential aspect of the timing is that it enables the government to issue new debt before retiring the old debt while having a maturity of one period on the debt. The need to roll over old debt into new is what drives the crucial results. A worthwhile extension of the model would be to have longer maturity debt that is only partially rolled over in any period and some stock of reserves with which the government pays old debt becoming due, but this would complicate the analysis.

Concept of equilibria and central results

Cole and Kehoe (1996b) carefully define a recursive equilibrium for their model. The crucial elements of this definition are policy functions that describe the optimal actions for each actor given the actions of other actors that have already occurred and taking into account the optimal responses that will follow.

For the domestic consumers, there is an optimal consumption policy c, and an optimal investment policy k_{t+1}. Each is a function of the aggregate state variable $s_t = (B_t, K_t, a_{t-1}, \zeta_t)$, the individual holdings of capital entering the period k_t (which in equilibrium is, of course, equal to the aggregate capital stock K_t), and the actions that have already occurred in the period relevant for the consumer's decision in the current period or for the determination of the aggregate state in the subsequent period, B_{t+1}, g_t, and z_t. Thus, consumers actions are determined by the policy functions

$$c_t = c(s_t, k_t, B_{t+1}, g_t, z_t)$$

$$k_{t+1} = k'(s_t, k_t, B_{t+1}, g_t, z_t).$$

The consumer's investment policy determines the evolution of the aggregate capital stock:

$$K_{t+1} = k'(s_t, K_t, B_{t+1}, g_t, z_t),$$

but the distinction between k_{t+1} and K_{t+1} is necessary so that individual consumers do not think they can influence the aggregate state, thereby manipulating the government and the international investors.

The behavior of the international investors is easy to summarize because they are competitive and risk neutral. The investors purchase the bonds B_{t+1} offered by the government as long as the price of these bonds satisfies

$$q(s_t, B_{t+1}) = \beta E z(s_{t+1}, B'(s_{t+1}), q(s_{t+1}, B'(s_{t+1}))),$$

in other words, as long as the expected gross return on these bonds is $1/\beta$. Here $z(s_t, B_{t+1}, q_t)$ is the government's optimal default policy still to be specified. The price function $q(s_t, B_{t+1})$ summarizes the behavior of the international investors.

The government is the only strategic actor in the model. After it has observed the actions of the bankers, which are summarized in the price q_t, it chooses whether or not to default, z_t, which in turn determines the level of government spending, g_t, and the level of productivity, a_t. This choice is given by the policy functions, $z_t = z(s_t, B_{t+1}, q_t)$ and $g_t = g(s_t, B_{t+1}, q_t)$. The state of the government when it chooses B_t is simply the aggregate state s_t. It knows, however, what the price $q(s_t, B_{t+1})$ and its own optimizing choices $g(s_t, B_{t+1}, q(s_t, B_{t+1}))$ and $z(s_t, B_{t+1}, q(s_t, B_{t+1}))$ will be later. It also knows the effects that its actions will have on the price of the bonds q_t, on the productivity parameter a_t, and on the consumers' consumption and investment decisions c_t and k_{t+1}.

Cole and Kehoe (1996b) demonstrate that there is always an equilibrium in which agents ignore the realizations of the sunspot variable ζ_t as long as the government prefers to repay its debt by setting $z_t = 1$. Furthermore, this equilibrium is stationary in that it satisfies $B_t = B$, $c_t = c^n$ and $k_t = k^n$, where

$$(1 - \theta)(f'(k^n) - \delta) = 1/\beta - 1$$

$$c^n = (1 - \theta)(f(k^n) - \delta k^n).$$

To calculate the maximum level of debt for which the government prefers to repay its debt, we need to calculate the levels of consumption and investment that will take place if there is a default:

$$(1 - \theta)(\alpha f'(k^d) - \delta) = 1/\beta - 1$$

$$c^d(k) = (1 - \theta)(\alpha f(k) - \delta k) - k^d + k.$$

Notice that, if there is a default, investment adjusts immediately to the stationary level k^d, but capital and consumption take one period to adjust because the initial capital stock k is not necessarily equal to k^d.

For the government to prefer not to default it must satisfy the constraint that the utility of not defaulting is greater than or equal to that of defaulting:

$$\begin{aligned}&[c^n + v(\theta(f(k^n) - \delta k^n) - (1-\beta)B)]/(1-\beta)\\ &\quad \geq c^d(k^n) + v(\theta(\alpha f(k^n) - \delta k^n) + \beta B)\\ &\qquad + \beta[c^d(k^d) + v(\theta(\alpha f(k^d) - \delta k^d))]/(1-\beta).\end{aligned}$$

Cole and Kehoe (1996b) refer to this constraint as the participation constraint. (They also show that an equilibrium without default may be possible even when this constraint is violated if the government reduces its debt immediately; this case is not very interesting, however, because there is no explanation of how the government could start with a level of debt high enough to violate the constraint.)

The government is in a very different position if it is not able to borrow from the international investors because $q_t = 0$. In this case it is optimal for the government to default if the utility of not defaulting is less than that of defaulting:

$$\begin{aligned}&c^n + v(\theta(f(k^n) - \delta k^n) - B) + \beta[c^n + v(\theta(f(k^n) - \delta k^n))]/(1-\beta)\\ &\quad < c^d(k^n) + v(\theta(\alpha f(k^n) - \delta k^n)) + \beta[c^d(k^d) + v(\theta(\alpha f k^d) - \delta k^d))/(1-\beta).\end{aligned}$$

Cole and Kehoe (1996b) refer to this condition as the no-lending continuation condition. If it is not satisfied, then it is not rational for the international investors to refuse to lend to the government.

The central result obtained by Cole and Kehoe (1996b) is, that, if both the participation constraint and the no-lending continuation condition are satisfied, then there are equilibria where default occurs with probability π for any $0 < \pi < 1$ as long as B_{t+1} remains in the interval where both of these conditions are satisfied. In particular, if $\zeta_t < \pi$ a crisis occurs, but if $\zeta_t \geq \pi$ it does not. Cole and Kehoe refer to this interval as the crisis zone. Actually, the crisis zone shrinks as π increases because that maximum level of debt that satisfies participation constraint falls. As long as there is a nonempty crisis zone for $\pi = 0$, however, then it is possible to show that there are levels of the debt for which a crisis occurs, at least in the first period, with probability π for any $0 < \pi < 1$. As long as B_{t+1} remains in the crisis zone q_t satisfies $q_t = \beta(1-\pi)$ and $k_{t+1} = k^\pi$ and $c_t = c^\pi$ where

$$(1-\theta)[(1-\pi+\pi\alpha)f'(k^\pi) - \delta] = 1/\beta - 1$$

$$c^\pi = (1 \quad \theta)(f(k^\pi) \quad \delta k^\pi).$$

Optimal government behavior is not necessarily stationary, however. In particular, for some levels of initial debt it is optimal for the government to run the debt down over time to leave the crisis zone.

A calibrated model and a lender of last resort

Cole and Kehoe (1996b) present a model designed to capture, in a stylized way, the situation in which Mexico found itself in late 1994. In this example a period is two-thirds of a year. This period length is chosen to match the average maturity of the Mexican government's short-term (that is, domestic) debt as shown in Table 3. The utility function for the consumers and the government is

$$E\sum_{t=0}^{\infty} 0.97^t(c_t + \log(g_t)).$$

The discount factor of 0.97 corresponds to a yearly discount factor of 0.955 ($=0.97^{3/2}$), which implies a yearly yield of 0.047 ($=0.955^{-1}-1$) on risk-free bonds – to be thought of as US Treasury bills. If we set the probability of default to be $\pi = 0.02$, then the yearly yield on Mexican government bonds – to be thought of as *tesobonos* – would be 0.079 ($=[(0.97)(0.98)]^{-3/2}-1$). Consequently, there would be a 3% risk premium on the Mexican government bonds. These numbers roughly match the average yields on 90-day US T-bills and 91-day *tesobonos* during 1994 (see Figure 5).

The choice of the funtional form $v(g) = \log(g)$ is somewhat arbitrary. In comparison with a function that displays more curvature, such as $v(g) = -g^{-1}$, this function allows the government a fair amount of substitutability in government consumption over time. This, in turn, allows the government flexibility in reducing its expenditure to be able to pay off old debt in the event of no lending. Consequently, setting $v(g)$ equal to $\log(g)$ rather than to $-g^{-1}$ increases the upper level of the debt for which no crisis can occur. The main point of the model is to show that crises can occur for fairly low levels of debt, however, and our choice of $v(g)$ biases, if anything, the results against crises.

The technology is given by the feasibility constraint

$$c_t + g_t + k_{t+1} - 0.95k_t + z_tB_t \leq 2k_t^{0.4} + q_tB_{t+1}.$$

The choice of $\delta = 0.05$ corresponds to a yearly depreciation rate of 0.074 ($=1-0.95^{3/2}$). The capital share 0.4 is lower than that found in Mexico's national income and product accounts, but the published numbers include income of self-employed workers in capital income. The constant in the production function is a scaling factor that only influences the results because the utility function $c + \log(g)$ is not homothetic.

If consumers expect default to occur nest period with probability $\pi = 0.02$, they set $k_{t+1} = k^\pi$ where k^π solves

$$(1-\theta)[(0.98 + 0.2\alpha)0.8(k^\pi)^{-0.6} - 0.05] = 1/0.09 - 1.$$

Setting $\theta = 0.2$ and $\alpha = 0.95$ – which implies that Mexico would incur a permanent drop in productivity of 5% if it were to default – we obtain a capital stock of $k^\pi = 39.04$ and a yearly GDP of $(3/2)2(k^\pi)^{0.4} = 12.99$, for a capital/output ratio of 3.00. The investment/GDP ratio is $0.05k^\pi/(2(k^\pi)^{0.4}) = 0.23$

(Banco de México 1995, p. 206, reports a ratio of 0.22 in Mexico in 1994). Government revenues as a fraction of GDP are $0.2(2(k^n)^{0.4} - 0.5k^n)/(2(k^n)^{0.4}) = 0.15$ (Banco de México 1995, p. 237, reports a figure of 0.17).

A crucial parameter of the model is the initial value of government, B_0. Choosing this parameter is complicated by the different types of debt obligations that Mexico had outstanding in 1994 and by the devaluation at the end of 1994 that sharply lowered the value of GDP compared to those obligations that were indexed to, or denominated in, US dollars. For the sake of discussion, we set $B_0 = 2$ for a debt/GDP ratio of 0.15, which is on the low side.

The crisis zone for this model includes all initial government debt levels in the interval $1.32 < B_0 \leq 8.49$, which are debt levels between 0.10 and 0.65 as fractions of GDP. For all debt levels in this zone it is optimal for the government to run the debt down and out of the zone, although this process can take up to 15 periods, which corresponds to 10 years. Furthermore, Cole and Kehoe (1996b) show that, if the government is more impatient than domestic consumers and international investors in that it has a discount factor $\gamma < \beta$, it may be optimal for the government to increase its debt even when it is in the crisis zone. Specifically, when $\gamma = 0.93$, which corresponds to an annual discount factor of $0.90 = (0.93^{3/2})$, it is optimal for the government to increase its debt for all levels greater than 2.21 (0.17 as a fraction of GDP). This process continues up to the upper limit of the crisis zone, which falls to 4.29 (0.33 as a fraction of GDP) because all actors now understand that the government is more impatient. (The lower limit of the crisis zone also falls, but only slightly.)

Cole and Kehoe (1996b) consider the case of government debt whose maturity is more than one period and show that as the maturity of this debt increases the crisis zone shrinks. This makes intuitive sense because, with debt of long maturity, the government needs to do little new borrowing in any given period, and consequently there is little difference between the situation where new borrowing is possible and that where it is not.

Let us consider another way of eliminating the possibility of self-fulfilling debt crisis. Suppose that there is a lender of last resort that stands ready to lend to the government at an interest rate $\bar{r} \geq 1/\beta - 1$. To receive this loan the government must be solvent in that it must prefer to repay any borrowing from the lender of last resort. Given a maturing debt of B, the government can smooth its consumption by setting its debt with the lender of last resort so that

$$\theta(f(k^n) \quad \delta k^n) - (1-\beta) - \theta(f(k^n) - \delta k^n) - B + D$$
$$= \theta(f(k^n) - \delta k^n) - \bar{r}D.$$

In other words, the government sets $D = \beta B$ initially and thereafter pays the debt service $\bar{r}D$. The constraint that the government be solvent is

$$[c^n + v(\theta(f(k^n) - \delta k^n) - \bar{r}D)]/(1-\beta) > c^d(k^n) + v(\theta(\alpha f(k^n) - \delta k^n + D)$$
$$+ \beta[c^d(k^d) + v(\theta(\alpha f(k^d) - \delta k^d))]/(1-\beta).$$

If $\bar{r} = 1/\beta - 1$, then this constraint is just the participation constraint: There is no crisis zone, and by its mere existence a lender of last resort can prevent a crisis and therefore never needs to make loans, at least in this simple model. If $\bar{r} > 1/\beta - 1$, however, there is still a small crisis zone, where the government would choose to refinance its debt at the low interest rate $1/\beta - 1$, but not at the high interest rate $\bar{r}$. It would then be the responsibility of the lender of last resort as a regulator to make sure that the government stays out of this crisis zone.

The analysis of this model suggests directions for future research. One obvious direction, already mentioned, would be to allow government debt instruments of various maturities and government reserves. Another would be to incorporate stochastic shocks to the production function so that the government might face some probability of finding itself in violation of the participation constraint. In this case the distinction between insolvency and illiquidity would be crucial, and the lender of last resort would need to be able to monitor the government's finances enough to make the distinction.

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