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Term Structure of Interest Rates Changes during International Financial Crises: The case of Argentina vs. USA

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"The crisis of this world is due to what happens far away, and powers have no longer location", from La empresa de vivir by Tomás Abraham.

Abstract

We bootstrapped spot rates for Argentinean and U.S. federal government debt instruments, and fitted them with *smoothing cubic splines*, a non-parametric method, to estimate the term structure of interest rates. When estimating the term structure one must decide how close should the data be fitted, considering that the curve should be flexible but should also maintain a certain degree of curve stiffness to identify misspriced securities. Smoothing cubic splines are a helpful tool to deal with this trade-off, since the degree of smoothing can be controlled with the smoothing parameter, which must be set between 0 and 1. Our approach is based on that presented by Fisher, Nychka and Zervos (1995); and to choose the "optimal" smoothing parameter value we applied both *generalized cross validation* and Reinsch's (1967) methods. The work analyzes the contagion effects that recent international financial crises such as the "*Tequila*" Mexican crisis, the Asian crisis, the Russian crisis, and the Brazilian devaluation had on Argentinean and U.S. term structures. It also analyzes what happened during the dates in which the 1999 Argentinean President's elections took place. We found that Argentinean curves changes were significant during all the crises, especially on short-term maturities. Nevertheless these changes were only temporary, since after some time, the curves went back to similar values and shapes to those that existed before the crises had begun. Finally, we applied a test for splines presented by Silverman (1985), based on Wahba's (1983) previous results, to analyze if the term structure changes were statistically significant or not. The confidence bands calculated by this method resulted too wide, and consequently they could not discriminate among significant and not significant changes.

Resumen

Calculamos las tasas "spots", sobre los títulos de deuda de los gobiernos nacionales de la Argentina y los Estados Unidos de América, a través del proceso conocido como "*bootstrapping*", y luego utilizamos funciones conocidas como "*smoothing cubic splines*" para estimar la estructura temporal de la tasa de interés. Al estimar la estructura temporal de la tasa de interés se debe decidir con qué grado la curva debe aproximarse a cada observación, teniendo en cuenta que se debería obtener una curva flexible pero debería también mantener un cierto grado de "suavidad", para poder identificar los títulos que no estén correctamente valuados. Justamente las "smoothing cubic splines" son funciones muy útiles en este sentido, ya que la "suavidad" de la función resultante puede ser controlada cambiando el parámetro de suavizado, que pertenece al intervalo [0,1]. Nuestro enfoque se basa en el presentado por Fisher, Nychka y Zervos (1995); y para elegir el valor "óptimo" del parámetro de suavizado utilizamos el método conocido como validación cruzada generalizada, o "*generalized cross validation*", y el método propuesto por C. Reinsch (1967). El trabajo analiza los efectos de contagio que las crisis financieras internacionales de los últimos años tales como la crisis del "*Tequila*" Mexicana, la crisis Asiática, la crisis Rusa, y el período de la devaluación Brasileña, tuvieron sobre la estructura temporal de intereses de Argentina y Estados Unidos de América. Se analiza también que ocurrió con las curvas durante los días de las elecciones presidenciales Argentinas de 1999. Encontramos que la estructura temporal de Argentina sufrió incrementos de nivel significativos durante todas las crisis, especialmente en el corto plazo. Sin embargo estos fueron cambios temporarios, ya que al corto tiempo, las curvas volvieron siempre a formas y niveles similares a los que existían antes de las crisis. Finalmente, para determinar si los cambios fueron estadísticamente significativos o no, aplicamos el test de splines presentado por Silverman (1985), basado en los resultados previos de Wahba (1983). Las bandas de confianza que este método calcula resultaron demasiado anchas para discriminar entre cambios significativos y cambios no significativos.

1 Introduction[2]

Recent international financial crises have had important contagion effects on Argentinean interest rates. But the effects on interest rates corresponding to different maturity horizons are usually very different. We can observe these differences through the *term structure of interest rates*, which is built on interest rates corresponding to financial assets with different time to maturity. But naturally, this curve is a continuous construction based on discrete observations, so it is very important the method we choose to fit the data points. Applying a reliable methodology to obtain precise estimations of these curve results essential for any person, company, or bank that deals with financial assets. Some of its most frequent uses are:

(i) ***Portfolio Management***. Fixed income investment managers choose among different assets for their portfolios using many criteria, out of which maturity – return relationship is one of the most important. That relationship is the term structure, which shows the correct return that should be obtained from commitments to different maturities. Managers rely on term structure analysis because shifts on this curve (parallel and not parallel) have significant effects on their portfolios, and today's shape can tell them a lot about expectations for tomorrow. They decide their investment policies partially based on this curve.

(ii) ***Identifying the Price of Time.*** Investors consider securities issued by the U.S. Treasury Department (Bills, Notes and Bonds) as credit risk free assets, since they are backed by the full credit of the U.S. Government. Therefore, the term structure of interest rates on these securities will represent the pure *price of time*. Using this information, credit risk spread on spot rates can be calculated for any other financial asset which was not issued by the U.S. Treasury Department.

(iii) ***Correct Pricing of Assets.*** The present value for any future payment should be calculated using the spot rate that corresponds to each maturity horizon, and the term structure

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of interest rates is built out from these rates. Identifying the correct price of financial assets is critical for analysts and traders when comparing two or more securities with the same credit worthiness. Having good information can take agents to identify arbitrage profit opportunities, for example stripping underpriced securities or synthesizing overpriced ones.

(iv) Future Interest Rates Reference. In financial markets, the agent that best predicts future interest rates can profit immensely. The analysis of the term structure of interest rates helps individuals know which is the market's consensus, so that they can make their own future conjectures.

(v) Expectations on the Real Economy. Future interest rate expectations have influence on the real economy's activity, including consumption and investment decisions. Today's economic activity depends on expectations on tomorrow's economic activity, and that's why term structure awareness is so important.

All these reasons illustrate the importance of good term structure estimations. To do so, we first bootstrapped theoretical spot rates out of yields to maturity for Argentinean government's debt instruments and U.S. Treasury securities, and then fitted those rates *with smoothing cubic splines*. Our approach is based on that presented by Fisher, Nychka and Zervos (1995). Then, we briefly explain how these splines work and which are the advantages of using them as fitting functions, as well as how could discount and forward curves be derived out of the spot rate curves (or term structures). To choose the "best" possible *smoothing parameter* value in the smoothing splines, we applied the *generalized cross validation* (GCV) method, and we also applied Reinsch's (1967) method, comparing the resultant splines. We found smoothing cubic splines particularly useful to fit Argentinean more variable and unequally time distributed observations. The work is centered in analyzing how Argentinean and U.S. term structure curves changed during recent international financial crisis periods. To incorporate more Argentinean debt instruments into the analysis we also fitted yields to maturity (since we could not bootstrap spot rates from non-bullet instruments[3]). Their graphs are shown in the appendix D. Finally, we applied the spline test presented by Silverman (1985), based in Wahba's (1983) previous results, but the confidence bands that this method calculated resulted excessively wide to discriminate among significant and non-significant changes.

This paper is organized as follows. In Section 2 we present the bootstrapping method, and the way in which discount and forward curves can be derived from spot rates curves. In Section 3 we explain how smoothing cubic splines work and we describe why we used them as fitting functions. Section 4 describes the assets we used and their characteristics. In Section 5 we present our results on term structure estimations, and in section 6 we apply a statistical test to study if the term structure curves suffered or not significant statistical changes. Finally section 7 presents our conclusions. Appendix A describes Argentinean government's debt general characteristics. Appendix B describes the Argentinean prices and yields we used, and Appendix C lists Argentinean federal government debt instruments. Appendix D presents the figures of the splines fitted on yields to maturity instead of spot rates, and in Appendix E we

[3] We used Matlab routines (see references) to do bootstrapping, and these can only bootstrap spot rates from bullet instruments.

briefly mention the hypotheses that have been postulated to explain different term structure shapes.

2 The Term Structure of Interest Rates

The *yield curve* is the relation between time and return to maturity for a set of assets with similar characteristics (credit risk, liquidity, etc.). When these returns correspond to zero coupon assets or *bullets*, we get the *term structure of interest rates*. And that is the curve that should be used to calculate the correct price for any financial asset and each of its components.

2.a. The spot rates

The *spot rates* are the return to maturity that zero coupon assets offer (Treasury Bills in the U.S. case, and "Letras del Tesoro" in the Argentinean case). The difference between *yields to maturity* (r) and *spot rates* (z), is that the second ones are the rates that correspond exclusively to a given maturity horizon, calculated on a given asset which has a single payment at that maturity, and no other coupon payments at other maturity horizons. This is therefore the rate that should be used to discount future cash flows. The problem is that zero coupon securities are usually short-term assets, and therefore the term structure of interest rates is not usually directly observable for medium and long term horizons. But we can derive medium and long-term spot rates by *bootstrapping* them out of medium and long-term non-zero coupon debt instruments information. In that case, each asset has to be considered as a package of independent future cash flows, with singular return and time to maturity. The following example explains this method, helping also to understand the difference between spot rates and yields to maturity.

Suppose we have a zero coupon asset which has 1 year to maturity, and with USD 1000 of face value. Given that it is a zero-coupon asset, the yield to maturity (r_1) that it offers will also be the 1-year spot rate (z_1). According to the financial theory, the present value of this asset (p_1) and these two rates should satisfy (2.1). If we can observe p_1, z_1 and r_1 can be found from:

$$p_1 = \frac{1000}{(1+z_1)} = \frac{1000}{(1+r_1)} \qquad (2.1)$$

Now suppose that longer zero coupon securities do not exist in the market, so the z_2 rate will not be directly observable. This is not a problem, because we can *bootstrap* spot rates out of yields to maturity. The following steps will show how this method finds the spot rates, and they will also show the conceptual difference between spot rates and yields to maturity.

Once we know z_1, we could calculate the z_2 rate. Suppose we chose a security with a 5% annual coupon rate, 2 years to maturity, and a face value of USD 1000. Knowing the price of this asset in the market (p_2) (determined with the yield to maturity (r_2) that it is offering), we can solve (2.2) to get z_2:

$$p_2 = \frac{50}{(1+z_1)} + \frac{1050}{(1+z_2)^2} \quad (2.2)$$

(Note that $p_2 = \frac{50}{(1+z_1)} + \frac{1050}{(1+z_2)^2} = \frac{50}{(1+r_2)} + \frac{1050}{(1+r_2)^2}$).

And once we got z_1 and z_2, using the price (p_3) of a three years to maturity security, and knowing that it also has a 5% annual coupon rate, and a face value of USD 1000, we can solve (2.3) to get z_3:

$$p_3 = \frac{50}{(1+z_1)} + \frac{50}{(1+z_2)^2} + \frac{1050}{(1+z_3)^3} \quad (2.3)$$

Following this approach, all the remaining theoretical spot rates: $z_4, z_5, z_6, \ldots, z_n$ could be derived[4]. That is, using similar assets but with different maturity dates, the j^{th} spot rate z_j can be found from:

$$p_j = \frac{50}{(1+z_1)} + \frac{50}{(1+z_2)^2} + \frac{50}{(1+z_3)^3} + \ldots\ldots\ldots + \frac{B_j + C_j}{(1+z_j)^j} \quad (2.4)$$

where C_j is the coupon payment and B_j is the principal payment of asset j.

2.b. The discount factors

According to financial theory, to find the arbitrage price for a future payment we should multiply it by the corresponding discount factor. Such factors can be derived out of the spot rates, as follows:

$$d_1 = \frac{1}{(1+z_1)^1};\ d2 = \frac{1}{(1+z_2)^2};\ldots.;\ dj = \frac{1}{(1+z_j)^j};\ldots.;dn = \frac{1}{(1+z_n)^n}. \quad (2.5)$$

where d_j is the discount factor we must use to get the present value of a future payment at period j. For example, to find the correct present value (PV) of a USD 1000 payment two years from now, where the two years annual spot rate is z_2, we should do:

$$PV = \frac{1000}{(1+z_2)^2} = 1000 * d_2 \quad (2.6)$$

[4] In case that more than one spot rate existed for a particular maturity date, the method uses simple average as the spot rate for that period.

2.c. The implied forward rates

Implied forward rates are very important variables for financial agents, and they should also be derived out of the theoretical spot rates curve. The following example shows the importance of this analysis.

Suppose that a person whishes to make an investment with two years of maturity horizon. The two alternatives could then be:

Alternative N°1: Buy security 1 with one year to maturity, and when it matures, buy another one with one more year to maturity.
Alternative N°2: Buy security 2 with two years to maturity.

Obviously the investor will be indifferent if both options give him the same overall profit. But the only known rates at the beginning of the first year are:

z_1: 1-year spot rate
z_2: 2-year spot rate

The *forward rate* (next years' one year spot rate) is not known at the beginning of year 1, but we can calculate which would be the rate that would let the investor indifferent among both options. This is the *implied forward rate* for year 2, (f_2), and can be solved out of:

$$(1+z_2)^2 = (1+z_1).(1+f_2) \tag{2.7}$$

The same can be done to get f_3:

$$(1+z_3)^3 = (1+z_1).(1+z_2).(1+f_3) \tag{2.8}$$

and so for: f_4, f_5,…., *fn*. To decide among the two mentioned securities, the investor will look at the f_2 rate. If he thinks that the future spot rate will be higher, he will buy security 1, and when it matures, buy another one-year security that offers the new spot rate. In contrast, if he thinks it will be lower than the f_2 rate, he will buy security 2 and keep it for two years.

2.d. Why are spot rates the correct rates for pricing financial assets? An example.

The most important reason for using spot rates to discount future payments is that every single payment should be discounted at its correspondent rate to identify arbitrage opportunities. If we used the yield to maturity to price a security, we would be using only one rate to discount all payments, thus obtaining incorrect present values for each coupon payment. Table 2.d. illustrates this concept. Suppose we observe in the market the yield curve which appears in column 3. This example uses 10 different securities with maturity in 10 different years from t=1 to t=10 (all with a 8% annual coupon rate (paid annually) and all with USD 1000 of face value), to bootstrap the spot rates corresponding to these ten years. In column 5 we calculate the present values (PV1) of *Bond A* 's cash flow payments separately (a 9% coupon security with USD 1000 of face value and ten years to maturity), using the yield curve values. And in column 8 we show the present values (PV2) of such payments but using the corresponding bootstrapped spot rates.

Table 2.d.

1	2	3	4	5	6	7	8
Years to Maturity (YTM)	***"Bond A"* Cash Flow (in USD)**	**Market YTM**	**Discount Factors (With YTM)**	**PV1 (in USD) (With YTM)**	**Bootstrapped Spot Rates**	**Discount Factors (With Spot Rates)**	**PV2 (in USD) (With Spot Rates)**
1	90,00	7,00%	0,9346	84,11	7,00%	0,9346	84,11
2	90,00	9,00%	0,8417	75,75	9,02%	0,8414	75,72
3	90,00	7,50%	0,8050	72,45	7,43%	0,8065	72,58
4	90,00	8,00%	0,7350	66,15	8,00%	0,7351	66,16
5	90,00	8,50%	0,6650	59,85	8,57%	0,6630	59,67
6	90,00	9,00%	0,5963	53,66	9,15%	0,5915	53,23
7	90,00	12,50%	0,4385	39,46	13,63%	0,4089	36,80
8	90,00	13,00%	0,3762	33,85	14,21%	0,3455	31,10
9	90,00	13,50%	0,3199	28,79	14,88%	0,2870	25,83
10	1.090,00	12,00%	0,3220	350,95	12,42%	0,3101	338,01
Total				**865,04**			**843,22**

It is easy to see that in this case, the *arbitrage* profit that could be obtained by synthesizing[5] the security and selling it at the price that some one could be calculating using the yield curve's values would be USD21,82 for every USD1000 (See that USD865,04 - USD843,22 = USD21,82).

Once those spot rates are found, we should still answer another type of questions. For example, suppose we wanted to know which should be the spot rate that a new security with 2.5 years to maturity be offering, and no other comparable security (risk, liquidity) exists in the market with the same maturity horizon (as you can see, in our example securities have 1,2,3,4,…,n years to maturity). Or for example suppose we wanted to know if certain security is well priced in the market according to the prices of similar securities except for the maturity. To answer such questions we must apply some method to estimate a continuos curve out of discrete observations. To do so, we used smoothing cubic splines, a non-parametric method that is described in the next section.

[5] Buying each coupon by separate and selling it as a package.

3 Fitting Spot Rates with Smoothing Cubic Splines

3.a. Smoothing cubic splines methodology

When choosing a function to fit bootstrapped spot rates, two opposed issues must be handled: fitting the data well and maintaining a proper degree of curve stiffness. If the function fits to the data extremely well, it will not identify misspriced securities in the market. On the other hand, if we choose a too smooth function, it will fail in fitting the data out of which it was supposed to be derived. We will explain how *smoothing cubic splines* help us to deal with this "precision–stiffness" trade off. This non-parametric method dates back at least to Wittakker (1923), and the method has been much studied and applied during the last 30 years. But despite this attention by specialists, the method is not as widely known and applied as perhaps it should be by practitioners.

We will now describe briefly how smoothing cubic splines work[6]. Suppose that we have observations (x_i, y_i) where i=1,2,…..,n and we want to fit a function on them. The fitting function g would then satisfy:

$$y_i = g(x_i) + e_i \tag{3.1}$$

It will be assumed that the x_i points satisfy $x_1 \leq x_2 \leq \ldots \leq x_n$, and that the errors e_i are uncorrelated with zero mean and standard deviation σ. The most common method to choose the function to fit the data would be to choose the one that minimizes the squared sum of errors, or what is the same:

$$\text{Min} \sum_{i=1}^{n} [y_i - g(x_i)]^2 \tag{3.2}$$

where $g(x_i)$ are the values that the estimative curve takes at the corresponding x_i.

Obviously if no other restriction is imposed on g, we will obtain a function that actually interpolates the data, taking to zero the sum of squared errors. But then, the resulting function would be too variable, and in our case, would fail to identify misspriced assets. The most common way of getting smoother functions is to restrict attention to a certain type of functions. For example, we could restrict attention to straight lines or logarithmic functions, or we could even use polynomial functions restricting their degree. But naturally, these functions would not provide the necessary variability to fit disperse data points[7]. Another way of reaching smoother functions is including a roughness penalty into equation (3.2). Equation (3.3) includes such roughness penalty, weighting it with (1-*p*). We will explain why smoother functions will produce lower values in this type of roughness penalty, but the idea is that

[6] The reader could see Carl De Boor's "A practical guide to splines" (1978), Silverman (1985), Fisher, Nychka and Zervos (1995), or Waggoner (1997), to find a more detailed theoretical explanation of the splines functioning.

[7] Large degree polynomial functions could show greater local variability, but these functions are too complicated and unmanageable.

minimizing Z_g, the resulting function $\hat{g}$ will produce a good fit to the data, and it will not show too much local variability. You can clearly see the trade off between getting closer to the data vs. obtaining smoother functions in equation (3.3), since both weights (*p* and *(1-p)*) sum up to 1.

$$\text{Min } Z_g = \left\{ \sum_{i=1}^{n} p.[y_i - g(x_i)]^2 \right\} + \left\{ (1-p).\left[\int_{x_1}^{x_n} [\partial^2 g(x)]^2 \, dx \right] \right\} \qquad (3.3)$$

Setting the smoothing parameter *p*=1 in this equation, the resultant function would actually interpolate the data, since the roughness penalty would be multiplied by 0. On the other hand, setting *p*=0 would only force the function to have the smoothest possible blends, resulting into the straight line that minimizes the square sum of errors. The interesting point of this method is that setting the smoothing parameter value between 0 and 1, the smoothing-local variability trade-off can be handled, fitting data well but maintaining certain degree of curve stiffness. As Silverman (1985) said, the *p value* represents the rate of exchange between residual error and local variation. The complicated task is choosing that "optimal" value, but fortunately several methods have already been proposed to do so.

As we mentioned, the roughness penalty is given by the integral of the squared second derivative of the function. But why does the integral of the squared second derivative of a function is increasing on that function's variability? Consider a function *g*. Now remember that the first derivative's *g'(x)* values will be low if the slope of *g* is not high, and that the second derivative's *g''(x)* values will be low if the *blends* (or first derivative's slope) of *g* are smooth. This condition is controlling that the function's *g* blends do not be too rough, and in this way, it is also controlling its slope (note that if the spline has a steep region downwards, and after that, a steep region upwards, the blend that these two generate will be too rough). The method first calculates the *g''(x)* function, and then calculates it's integral in order to find if the values of that function are high or not. Remember too that the integral on a function calculates the area under the curve, so if the values of the *g''(x)* function are high (as a consequence of too many rough blends in the *g* function) the integral values will also be high. The square on *g''(x)* in equation (3.3) avoids that negative and positive values balance each other, by making all of them be positive values. Summarizing, as the function's variability increases, the integral on the squared second derivative value will increase too, increasing the roughness measure.

Now, it can be shown (see Reinsch (1967) and (1971); or Greville (1969)), that if Z_g is minimized over all twice differentiable functions *g*, given a smoothing factor *p*, and given that i=1,2,…,n; the resulting curve $\hat{g}(x)$ has the following properties:

(a) It is a cubic polynomial[8] in each of the subintervals $[x_i, x_{i+1}]$;
(b) At the points x_i, the curve and its first two derivatives are continuous, but there may be a discontinuity in the third derivative;
(c) In each of the ranges $(-\infty, x_1)$ and (x_n, ∞) the second derivative is zero, so that $\hat{g}$ is linear outside the range of the data.

[8] Remember that cubic polynomials are of the form: ax^3+bx^2+cx+d, where a, b, c, and d are the polynomial's coefficients.

Any curve which satisfies (a) and (b) is called a *cubic spline with nodes* x_i. These are not imposed on the estimate, but are a consequence of the minimization in equation (3.3). A *smoothing* cubic spline is a piecewise cubic polynomial, joined together at *node points*, which naturally includes a roughness penalty and therefore allows us to choose the smoothing degree. At every *node* point, the two polynomials that meet will have exactly the same level and first two derivatives. That is, they will meet, and they will do it smoothly. This is the approach we followed, previously applied by Fisher, Nychka, and Zervos (1995).

Some authors used other methods to smooth cubic splines, for example McCulloch (1975). Cubic splines' flexibility depends on the number and spacing of the node points. By reducing their number or increasing their spacing, McCulloch (1975) managed to control the splines' oscillations. Though the number of nodes and their spacing are ad hoc in his model, he found that this methodology worked fairly well in practice[9].

Waggoner (1997), observed that cubic splines tend to oscillate excessively on long-term maturities, while failing to fit short-term observations. To solve his problem, he designed a method to fit smoothing cubic splines that resulted more flexible in the short end than in the long end. Smoothing cubic splines flexibility depends not only on the nodes number and spacing, but also on p. This author postulated that when a fixed p is used, and as p increases, the value of that parameter influences the variability of the spline more than the nodes number and spacing do. And therefore, if a constant p is used, and if that p value is not low, the resulting splines would show long term excessive oscillations, no matter how the nodes are settled. To solve this, he proposed a *variable smoothing parameter*, *p(x)*, decreasing on maturity, transforming the roughness penalty term on equation (3.3), into a *variable roughness penalty*. This variable parameter would allow him to get a $\hat{g}$ spline function that could fit short-term spot rates more closely than long term spots. For that he grouped data points according to their abscissa position, and used different p values for different maturity regions. For longer maturity regions, his method would set lower p values, which would force the resulting spline to be smoother. Therefore, the objective function to be minimized would be (3.4). Note that this equation is the same as (3.3), except that the smoothing parameter is now depending on x.

$$\text{Min}\, Z_{g(Wag)} = \left\{ \sum_{i=1}^{n} p(x).[y_i - g(x_i)]^2 \right\} + \left\{ [1 - p(x)] \left[\int_{x_1}^{x_n} [\partial^2 g(x)]^2 \, dx \right] \right\} \qquad (3.4)$$

But we could well fit splines that are smoother in long-term maturities than in short term maturities using the model applied by Fisher, Nychka, and Zervos (1995). Equation (3.5) incorporates w, a (1xn) vector (with $w_i \in (0,1)$ for all $i \in (1,n)$, which indicates to the spline the importance we want to assign to each data point (x_i,y_i). For example, if we wanted to fit a spline avoiding long term oscillations, but fitting short term zeros well, we could set w=[1,1,1,…, ½, ½,……,½]. The objective function to be minimized in order to obtain our smoothing cubic spline would then be:

[9] The suggested number of node points is approximately the square root of the number of observations used in the sample, and they should be spaced so that roughly an equal number of observations fall between nodes. For a more complete description of his method see McCulloch (1975).

$$\text{Min } Z_{g(w_i)} = \left\{ \sum_{i=1}^{n} p.w_i.[y_i - g(x_i)]^2 \right\} + \left\{ (1-p).\left[\int_{x_1}^{x_n} [\partial^2 g(x)]^2 \, dx \right] \right\} \quad (3.5)$$

Note that this is also the same as (3.3), but now we can assign different importance to each data point in the sample. In other words, this would be the other way of dealing with the regional oscillatory problem that Waggoner found. Assigning smaller weights on long-term observations, the resulting spline would fit short-term rates better than long-term rates, and therefore avoiding excesive long-term oscillations.

Anyway, we set w_i=1 for all i, and used a fixed *p* value (not dependent on x), because our splines did not present the oscillations on long term maturities that Waggoner (1997) tried to solve.

The advantage of using a non-parametric method versus using parametric methods is that the estimated values of the curves will not depend on all data points in the sample with the same weight[10]. Near data points will have much more influence on the curves' estimated values than distant points, giving us much more "consistent" estimations of the term structure curves.

3.b. Choosing an "optimal" value for the smoothing parameter

We could simply start plotting splines with different smoothing parameter values, until we get that one that "looks better", or we could use a pre-specified model to choose an "optimal" value. Several methods have been proposed to define such "optimal" value, and asymptotically, all these methods should arrive to similar results, since they are all trying to find the "optimal" value.

We used a well-known method called *generalized cross validation* (GCV), (the reader can see Wegman and Wright (1983) or Silverman (1985) for a specific treatment of the GCV methodology), applied by Fisher, Nychka and Zervos (1995) too. This method applies a "take-one-out" technique to find which is the smoothing parameter value under which the missing data point is best predicted by the remainder of the data. More precisely, the method works like this: first, the first observation is left out of the sample, and finds $\hat{g}*_{p*[-1]}$, which is the spline that using as smoothing parameter p* minimizes (3.6) [11]. Then, the second observation is left out, and finds $\hat{g}*_{p*[-2]}$. The same process is repeated to find $\hat{g}*_{p*[-i]}$ for all i, trying every possible *p* value between zero and one, by minimizing Z_i:

[10] For example fitting a linear function such as $y_i = \beta x_i + e_i$ or a logarithmic one such as $y_i = \beta.\log(x_i)+e_i$, the only parameter to be estimated would be β, so the value of the first data point in the sample will influence the value that the resultant estimating curve takes near the last data point.

[11] We used cubic splines here too, but other type of splines could have been used.

$$\text{Min } Z_i(gcv) = \left\{ \sum_{i=1}^{n} p.w_i.[y_i - g_{p.[-i]}(x_i)]^2 \right\} + \left\{ (1-p).\left[\int_{x_1}^{x_n} [\partial^2 g_{p.[-i]}(x)]^2 \, dx \right] \right\} \qquad (3.6)$$ [12]

When all the $\hat{g}*_{p*[-i]}$ splines have been found, the sum of squared errors between them and all the data points (including the one that had been left out of the sample for each spline) is calculated. Out of the $\hat{g}*_{p*[-i]}$, the one that minimizes (3.7)[12] is chosen, and the $p*_{-i}$ that generated that spline is chosen as the "optimal value.

$$\text{Min } CV(p) = \frac{1}{n} \left\{ \sum_{i=1}^{n} [y_i - \hat{g}*_{p*[-i]}(x_i)]^2 \right\} .w_i \qquad (3.7)$$

The idea is that it chooses the $p*$ value that generates the $\hat{g}*$ *smoothing cubic spline* that would calculate the most probable values for data points if missing in the sample. We used Woltring's B-Spline algorithm[13] to apply *generalized cross validation*.

We also used the method presented by Reinsch ([1967]; [1971]) to select an appropriate smoothing value. He demonstrated that a sensitive range[14] for p is around:

$$p* = \frac{1}{1+\theta} \qquad (3.8)$$

[12] We used w_i=1 for all i here too.

[13] To use this algorithm within Matlab workspace, we used Matlab mex interface for GCVSPL package contributed by Anthony Reina's (April 1998), based on Dwight Meglan's C code. Actually the GCVSPL pack works with this equation:

$$Z(gcv) = \left\{ \sum_{i=1}^{n} w_i.[y_i - g_{p.[-i]}(x_i)]^2 \right\} + \left\{ \lambda \left[\int_{x_1}^{x_n} [\partial^2 g_{p.[-i]}(x)]^2 \, dx \right] \right\} \qquad (3.6)'$$

where $0<\lambda<\infty$, instead of (3.6). Knowing the value of λ we can get the value of p, and the other way too. Note that if we multiply (3.6) by any constant, the solution will not change. Then, multiplying it by 1/p, we will get (3.6)', where $\lambda = \frac{1-p}{p}$; and therefore we can get the p value from: $p = \frac{1}{1+\lambda}$ if we had λ. Therefore, the splines using 1 and λ as weights, and the splines using p and (1-p), will result exactly equal (we verified this ourselves). We did this, because the routine that fits smoothing cubic splines within Matlab requires the "p" value as an input, but as we explained, the routine that runs GCV within that software outputs the "λ" value.

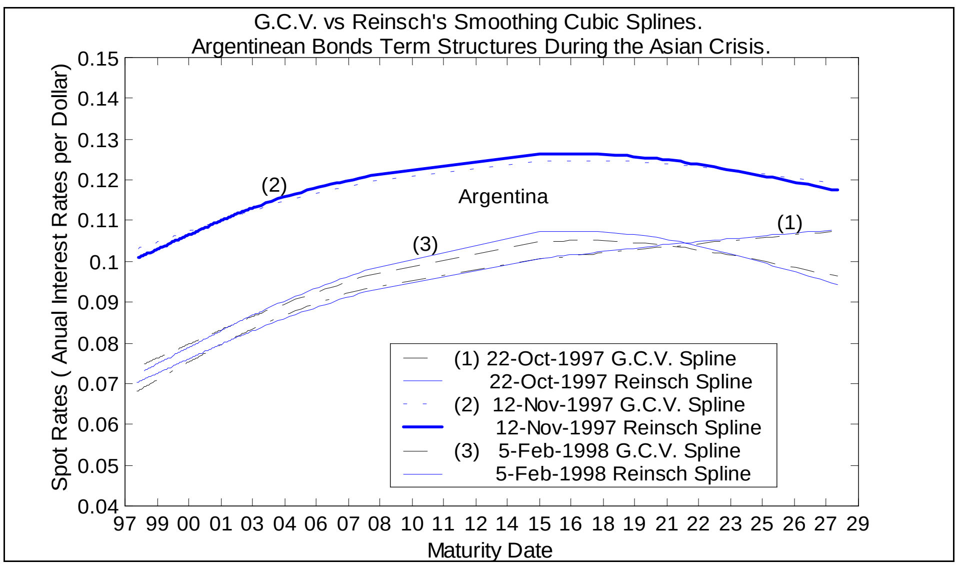
[14] This means that within this range, the splines' variability is significantly affected by changes in the smoothing factor, but outside this range, it is not. Therefore, Reinsch (1967) and (1971) postulated that it's enough to work inside this range, because almost all splines can be found here.

$$\text{where: } \theta = \frac{h^3}{16}$$

and h is the maximum difference between the given abscissas. Specifically, one would expect a close following of the data when $p = p_{\text{fit}} = 1/(1+\theta/10)$ and some satisfactory smoothing when $p = p_{\text{smooth}} = 1/(1+\theta.10)$. This result is proven in Reinsch (1967) and (1971) [15].

We calculated smoothing factors with both methods and compared the resultant splines. Figure 3.b. presents the smoothing splines fitted on Argentinean term structures during the Asian crisis period. This is a good example of what we found in most cases: Reinsch's smoothing values and *generalized cross validation* values generated similar splines, confirming that actually the smoothing parameter's choice from both methods would tend to converge.

Figure 3.b.



4 The Assets

4.a. The Argentinean security markets

Argentinean security markets are regulated by the "*Comisión Nacional de Valores*" (National Securities Commission or "C.N.V."). In Buenos Aires, (Argentinean national capital), securities trade both at the "Bolsa de Comercio de Buenos Aires S.A." (Buenos Aires Stock Exchange or "B.C.B.A."), and at the "Mercado Abierto Electrónico S.A." ("M.A.E.").

[15] Reinsch's easy way of choosing the "optimal" smoothing parameter is presented too in Carl de Boor (1999), Spline Toolbox User Guide, The MathWorks Inc., pp.2-17, Version 2.0.1. Release 11.

The B.C.B.A. is older (founded in 1854) but not more important than M.A.E., which started operations in March 1989. There are other Stock Exchanges in Argentina which are also authorized to trade securities, but none of them is important.

Argentinean government debt instruments market has grown significantly during recent years. In 1987 and 1988, Argentina issued the "New Money Bonds" and the "Alternative Participation Instruments" (APIs) as a result of the restructuring of an existing debt with commercial bank creditors. On December 28th 1989, all Government debt instruments other than "Bonex" (which first series, "Bonex87", had been issued in 1987) were refinanced into "Bonex 89" pursuant to the Government stabilization measures. After that, in 1990 and 1991, the Government started issuing USD denominated debt instruments called the "Botes" (Bonos del Tesoro). In 1991, another important series began to be issued: the "Bocones". In accordance with the Debt Consolidation Law (Law 23.982), the Government issued six series of "Bocones" (Bonos de Consolidación) during 1991 and 1992, to pensioners and various private creditors for amounts owed to such creditors which had accrued but had not been paid (new "Bocones" series were later issued in 1994 and 1999). For this time, (in April 1992), the Government announced a new refinancing agreement to restructure medium and long term debt. It consisted on the issuance of Par bonds, Discount Bonds, and Floating Rate Bonds (FRB), known as Argentinean Brady Bonds. From these, the Discount and the PAR bonds are the only Argentine debt instruments that count with warranty[16] of the U.S. Treasury.

In 1993, Argentina started issuing a new series of plain vanilla debt instruments called "Globales" (Global Bonds), as well as Argentinean "Eurobonds". And finally, in 1996 the Government began to issue short term Treasury bills known as "Letes" (three, six, and twelve month securities), together with medium and long term Treasury bonds known as "Bontes" (Bonos del Tesoro). Table C.1. in Appendix (C), presents detailed information on all Argentinean government debt instruments[17].

Argentina's indebtedness has been divided into "External Indebtedness" and "Domestic Indebtedness". Under the first category we have Global Bonds, Brady Bonds, and Eurobonds. All the rest of Argentinean government debt instruments correspond to the "Domestic Indebtedness" category. Even though the "Bonex" and the "Bontes" series correspond to the "Domestic" group, they are included under the "*cross default*" regime. Basically, this establishes that if Argentinean Government fails to pay any interest or principal corresponding to any security classified as "External Indebtedness", holders may declare at the office of the fiscal agent the principal amount to be immediately due and payable. Usually "Bonex" and "Bontes" where said to have "half cross default backup", since the government should pay their principal amount (if claimed) if default occurs on any other "External" security, but not the other way. In May 1999, these series where reclassified as "External Indebtedness", so we can now say that they count with a "full" cross default warranty.

Obviously this "cross default" regime improves the "quality" of the instruments, since the Government would have incentives to default on any other before defaulting on them. This is the reason why financial analysts plot two USD Argentinean term structure curves:

[16] The warranty backs two coupon payments and 100% of the principal payment.
[17] Eurobonds are not included in this list because we considered securities that trade in Argentinean markets, and eurobonds don't.

one for debt instruments having some kind of "cross default" backup, and other one for the ones which do not have so[18].

The Convertibility Plan, the trade liberalization measures, the elimination of restrictions to foreign capital movements and other important economic measures adopted by the Government during this decade have reactivated Argentina's economy. In the past, Argentinean Government defaulted on loans from commercial banks, from governmental creditors, and on bonds issued as part of previous debt restructuring with commercial banks. Since 1993, all payments with respect to domestic and foreign currency denominated debt have been made on a timely basis, but Argentinean securities continue to offer high rates over U.S. Treasury securities.

4.b. The data we used

In the case of Argentinean debt instruments, we considered closing day prices published by M.A.E. S.A. in it's "*Boletin Diario*" and yields to maturity[19] calculated by them too, since the majority of Argentinean government debt instruments are traded at this exchange. In the case that an instrument did not trade at M.A.E. exchange for a given day, we considered closing prices at the Buenos Aires Stock Exchange, and yields to maturity calculated by the I.A.M.C. (Instituto Argentino de Mercados de Capitales S.A.) which is associated to the B.C.B.A[20]. This information is published in the "*Informe Diario del I.AM.C.*". Finally, if that security didn't trade at the B.C.B.A. either, we used prices published by Mercado Abierto S.A. (an important broker company in Argentina) in "*Ambito Financiero*" (a well known financial newspaper)[21].

Argentinean government debt instruments market is increasingly important and worthy of study. Nevertheless, the number of Argentinean instruments is much smaller than U.S. treasuries, and even worse, we must separate them into different groups. We considered instruments issued in USD, and separated them into two groups: bullet instruments (those that

[18] Some analysts postulated that Argentinean securities should be grouped according to their issuance procedure. That is, the "Bocones", and the "Bonex" series where issued to pay old Governments' debts which had accrued but had not been paid. Since the Government "forced" these creditors to take these instruments as payment, these securities are classified as "compulsive" debt. On the other hand, the rest of Argentinean securities such as the "Bontes" or the "Globales", where issued and sold at domestic and International Markets through public offers. Agents who bought these securities did so voluntarily, and therefore Argentinean debt which is not "compulsive" is said to be "voluntary". Nevertheless, we considered that credit risk has little to do with this fact, but depends on the probability that the Government would default on certain instrument or not. Following this criterion, we separated USD securities into securities which are under the "cross default" regime, and securities which are not.

[19] For those Argentinean Securities with floating rate coupons, yields to maturity where calculated using current values on the corresponding rates. We used all Argentinean securities that existed for each date.

[20] Within the Buenos Aires Stock Exchange there are two systems to trade securities. On one hand we have the "Mercado de Concurrencia" which is formed by the "Piso" transactions, and the SINAC transactions (electronic offer and demand). And on the other we have the "Rueda Continua de Negociación", which is a parallel market where no public offers or demands need to be done. Transactions are made among two agents that get in touch through a computing system and negotiate on the transaction conditions (price and amounts). We used, as well as the I.A.M.C. does, prices from the "Mercado de Concurrencia".

[21] They publish prices that do not necessarily refer to Buenos Aires markets, but they are as representative as prices published by M.A.E. or the B.C.B.A.

pay 100% principal when they mature), and non-bullet instruments[22]. Since we used Matlab routine for *bootstrapping*, and as this can only bootstrap spot rates from bullet instruments, we could only bootstrap spot rates for the first group. The amount of Argentinean government debt instruments in the first group was increasing during recent years, but usually we did not count with more than 15 observations[23]. All these instruments can all be fit with the same curve since they belong to the same quality group, for been all under the cross default regime.

To incorporate non-bullet debt instruments into the analysis, we fitted yields to maturity for all Argentinean instruments issued in USD, separating them in two groups: those which are under the cross default regime (group 1), and those which are not (group 2). The figures in Appendix D show those two curves for every date we analyzed. With respect to the two Argentinean debt instruments counting with U.S. Treasury warranty on their payments (PAR and Discount), we did not included them in any of the groups, because their quality is considered to be better than all the rest. We could not, obviously, fit separate splines on their rates, because these are only two.

During the "Tequila" Mexican Crisis period, only one Argentinean bullet instrument existed, so we fitted splines on yields to maturity instead of doing it on spot rates, in order to get an approximation to the Argentinean term structure. Instruments under the "cross-default" regime were not common during those dates in Argentina, so the curves for the "Tequila" dates in the next section correspond to non-bullet USD instruments with no "cross default" (group 2). This is the reason why the "Tequila" crisis peak curves are not shown in figures in section 5.g. when we compare all the crises.

For U.S. Treasury Bills, Notes and Bonds, we used prices and yields to maturity which are daily published by the "New York Times" newspaper[24]. Callable bonds where taken out of the data since a callable bond will trade at a substantially lower price than a similar non-callable bond when interest rates drop below the coupon rate of the callable bond. This is due to the increased likelihood that the bonds will be called by the issuer. For Argentina's case we left callable bonds into the data because the number of securities was already significantly lower.

[22] For Argentinean peso denominated instruments we did not fitted splines because we had a significantly small number of observations (usually not more than 5). With respect to Eurobonds, such as instruments in German Denmarks, Italian Liras, Japanese Yens, Swedish Franks, British Pounds, or Spanish Pesetas, we did not include them in the sample for two reasons. First, these do not trade in Argentinean markets, and second, their yields to maturity are not straightly comparable between each other or with USD denominated instruments because of the currency difference.

[23] We found that these small numbers of observations in each group did not make smoothing splines inaccurate. We used all Argentinean securities that existed for each date.

[24] We were unable to purchase any existing data store, due to restrictions in our budget.

5 Results

5.a. Choosing dates for our analysis

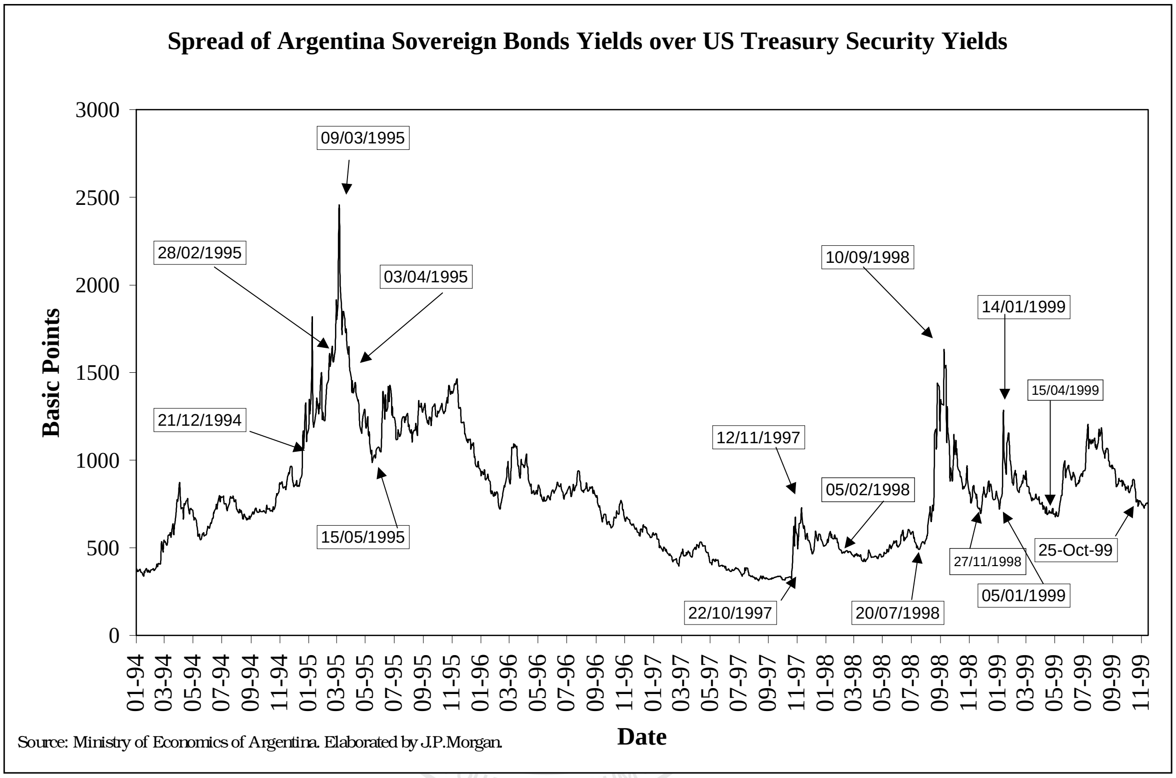
As we already mentioned, we analyzed how the Argentinean and the U.S. term structure of interest rates fluctuated due to the effect of international financial crisis. These crises were the "Tequila" Mexican Crisis of 1994-1995, the Asian crisis of 1997, the Russian financial crisis of 1998, and the Brazilian devaluation period of 1999. We also analyzed how Argentinean president's 1999 election affected Argentinean curves. To choose the dates in which we bootstrapped and fitted curves[25], we looked at the country risk index calculated by J.P.Morgan named "EMBI-Argentina"[26] (Emerging Markets Bonds Index for Argentina), which includes various Argentinean bonds. This index weighs bond prices using their market-capitalization[27], corresponding to the prior business day. Figure 5.a. shows the evolution of this index, and its level at the dates we have chosen. As we see, these dates correspond to the minimum points before the crises exploded, the maximum points that this index reached during those periods of financial turbulence, and a day in which the crisis had already finished. For the "Tequila" banking crises period, we chose 5 dates, based on Dabós and Gómez Mera (1999) analysis of the crisis evolution. For the 1999 President's election period we simply considered the day before and the day after the election took place.

[25] We would have liked too, to bootstrap spot rates for every day since 1994 up to 1999, but Argentinean Prices and Yields were not stored by Bloomberg, Reuters or other financial data supplier, on a daily basis, since that time. We would have liked that such information existed for Argentinean securities, to plot 3-D graphs as many authors did, and analyzed the continuous change of the curves. This was done for example by Bing-Huei Lin, in "Fitting the term structure of interest rates for Taiwanese government bonds", Journal of Multinational Financial Management, 1999, for Taiwanese term structure curves; or by Fisher, Nychka and Zervos, in "Fitting the term structure of interest rates with smoothing splines", Federal Reserve Board, January 1995, for the U.S. Treasuries curves.

[26] The EMBI-Argentina covers Argentinean Brady Bonds. The EMBI$^+$-Argentina includes some other Argentinean non-brady bonds, but we considered that it was not significantly different which one we used from these two to choose our dates, since they are highly correlated (Correlation Coefficient = 0.98).

[27] Each proportional amount or weight in this index is a function of both the amount outstanding (which we will assume is equal to that proportion of an asset's outstanding amount that an investor can easily purchase) and it's price. These two factors, when multiplied together, equal the asset's market capitalization. To calculate the spread with respect to U.S. Treasuries, a weighted average (using the assets market capitalization) on the maturity of Argentinean securities is calculated, and then it is compared with an equivalent U.S. Treasury security. See Vandersteel Tina, "Emerging Markets Bonds Index Plus Methodology", Emerging Markets Research, J.P.Morgan Securities Inc., New York, 12 July 1995, for an extensive description of this Index's methodology.

Figure 5.a. Spread between the EMBI Index and U.S. Treasuries Yields[28]



5.b. The "Tequila" Banking Crisis

On December 20th, 1994, the Mexican Central Bank established the widening of the exchange rate bands, which resulted in an immediate 15% devaluation of the Mexican currency. The devaluation of the peso continued, and the fall in international reserves deepened, leading the authorities to announce the floating of the peso two days later. The confidence crisis triggered by the Mexican devaluation reached the emerging markets. Argentinean stock exchanges indexes and government bond indexes fell substantially. On the other hand, the Asian and the industrialized western countries stock markets evolved favorably after the Mexican peso devaluation.

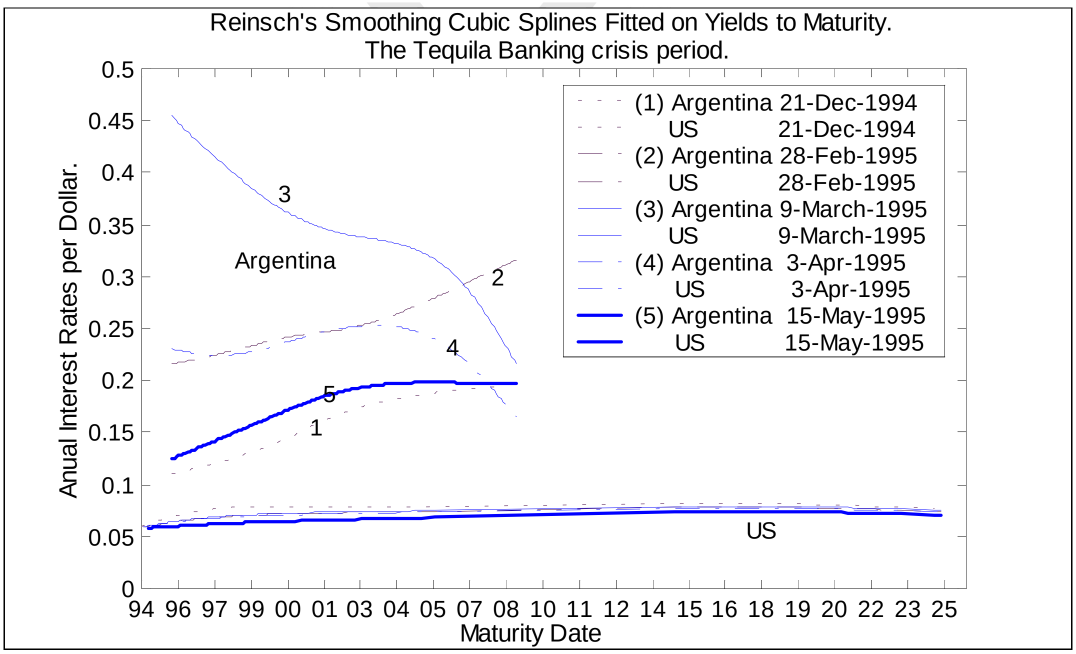
The effects that this crisis had over Argentinean financial markets can be divided into 5 phases (see Dabós and Gomez Mera, 1999). During the first phase, which started the day the Mexican Peso was devalued, and finished at the end of February, there was an important process of peso deposit withdrawal and a reallocation of deposits among financial institutions. The second phase took place during the month of March. During this second phase, the fall in deposits became a true bank run affecting both peso and dollar deposits, and extending to all groups of financial institutions. At the same time, interests rates reached their highest levels. During the third stage of the crisis, from April until the middle of May, the deposit

[28] The dates format will be in all our work: dd/mm/yy.

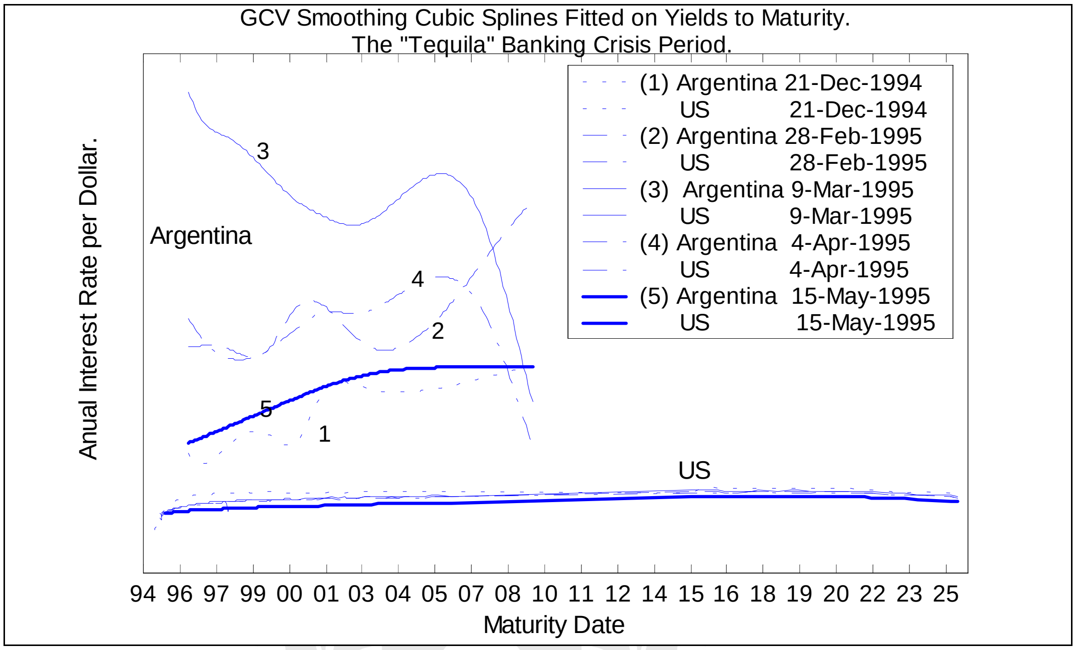
withdrawal slowed down, until it was reverted in May 15, when the forth and last period of recovery began.

Based on this analysis, we chose five dates to fit the term structure splines: December 21st1998, February 28th 1995, March 9th 1995, April 4th 1995, and May 15th 1995. As we said, the securities included in group 2 for the yield curve analysis are non-bullet bonds denominated in USD, and which are not under the cross default regime or count with U.S. Treasury back-up on their payments. The Discount and Par bonds count with U.S. Treasury warranty on their payments, and as we said, that is the reason why we did not include them in group 2. Given that these were the only securities that for that time had maturities longer than 8 years, the resulting Argentinean yield curves presented in these two figures had only 8 years of maturity horizon. Figures 5.b.i. and 5.b.ii. present our results for the five dates we mentioned, using generalized cross validation and Reinsch's methods to choose the smoothing parameter in the splines.

Figure 5.b.i.



<u>Figure 5.b.ii.</u>



As we can see from both figures, during the first phase, short and long Argentinean rates suffered a significant increase. After that upward parallel shift, the term structure reversed. This could be interpreted in the following way: for March 9th 1995, though interest rates reached their highest levels in Argentina, and the crisis was at it's worse moment, individuals expected interest rates to fall in the short-medium term. Argentinean yield curves showed a significant downward shift from March to April, with short-term interest rates falling more than long term ones, resulting into a relatively flat shaped curve for April 4th, 1995. On May 15th the curve had already come down to the values and shape that existed before the crisis had began.

6.c. The Asian Crisis

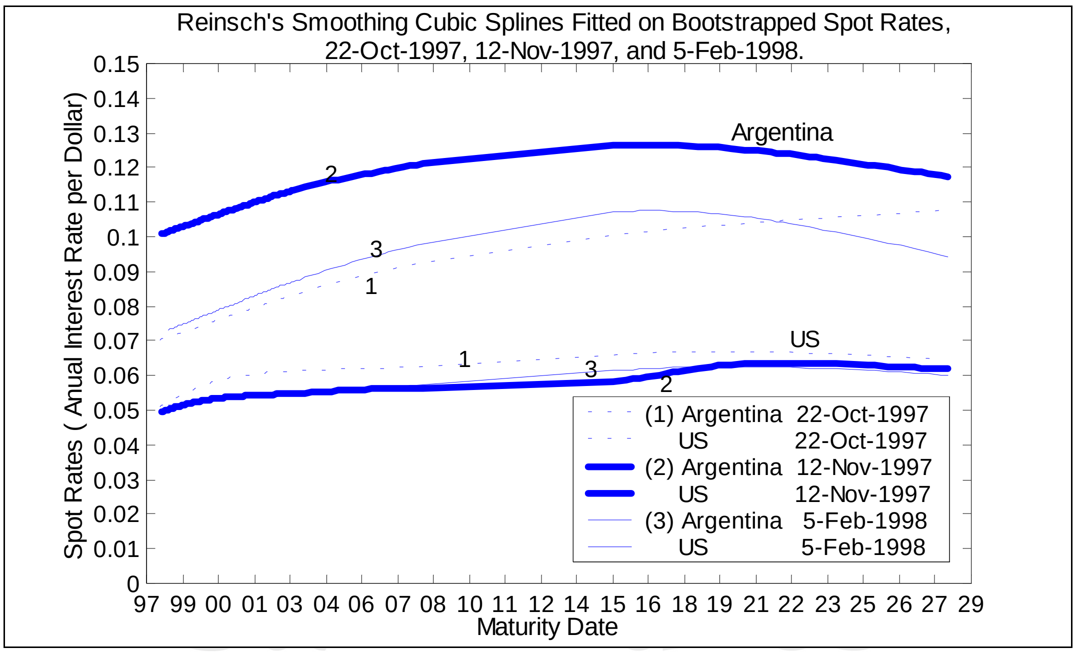
The economic and financial crisis that took place in several Asian countries in 1997 not only spread into other economies in that continent, but caused spillover effects throughout the global financial system. This crisis had its origin in the large-scale shift of funds out of domestic financial markets, beginning in Thailand[29]. The International Monetary Fund postulated that four basic factors contributed to these crises to occur. First, the successful performance of these countries during the early and mid 90's; second, some favorable external conditions during pre-crises years, third, some inconsistencies in macroeconomic and exchange rate policies, and forth, various structural weaknesses in their economies, particularly in their financial systems. It is not our objective to explain why this crisis

[29] See Benton E. Gup, 1999.

occurred, but we only intend to describe how Argentinean and U.S. term structure curves where affected.

Despite the apparent difference between Asian and Latin American economies, the second ones were significantly affected by the crisis. Almost all Latin American countries suffered important loses in equity markets by the end of 1997, as well as interest rate and yield spreads rises. Argentinean EMBI-Arg. Index reached 729 basic points for November 12th 1997, which indicated the important shock that this economy received. Figures 5.c.i. and 5.c.ii. show the estimated term structures for October 22nd 1997 (when country risk was only 324 basic points), November 12th 1997, and February 5th 1998 (when country risk had already gone down to 481).

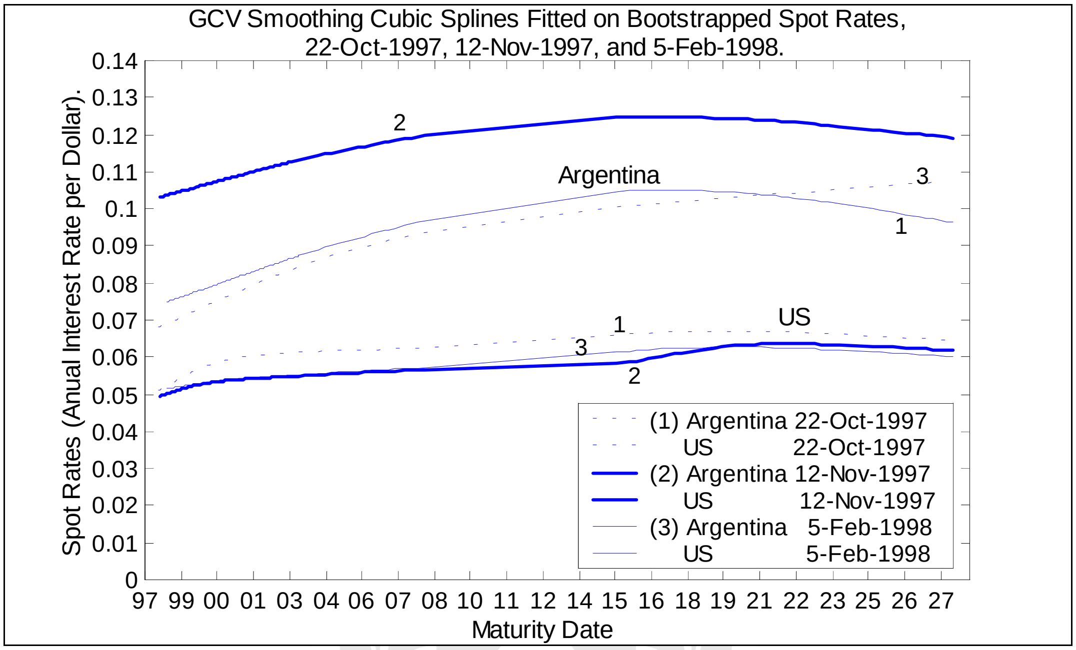
Figure 5.c.i.



First of all, we should note that here too, both methods to calculate the optimal smoothing parameter conducted us to similar spline functions.

With respect to the Argentinean term structure estimations, it can be seen that it suffered a significant parallel upward shift during this crisis. We could then say that investors expected Argentinean interest rates to remain high for a long time. But rates went down relatively rapidly, and for January 5th 1998, spot rates had already gone down to similar levels to those that existed before the crisis. Looking at the U.S. term structure estimations, we can see that spot rates went down during the crisis, increasing even more the spread on spot rates between Argentinean bonds and U.S. Treasuries. The crisis had opposite effects on Argentinean and U.S. curves, but note that Argentinean spot rates increased much more than what U.S. spot rates decreased.

Figure 5.c.ii.



5.d. The Russian Crisis

The Russian financial crisis had its origin in its large fiscal deficit and a financial system with serious structural problems.(see Benton Gup (1999)). On August 17th, 1998 Russia's authorities announced a package design to deal with the currency, debt, and banking crises. The ruble was devalued and it was then announced that a compulsory restructuring of Russia's domestic debt would take place. These facts had also a big impact on Argentinean markets, causing the EMBI-Arg. Index to reach its highest level since the Mexican Banking crisis period. It reached 1,626 basic points in September 10th 1998, despite the efforts of Argentinean authorities to differentiate Argentinean economic position from that of Russia. We also present curves corresponding to July 20th 1998 (country risk was just 498 basic points) and November 27th 1998 (when it had already gone down to 783). The following two figures show the splines on spot rates for these three dates, using Reinsch's and GCV smoothing parameters for smoothing splines.

Figure 5.d.i.

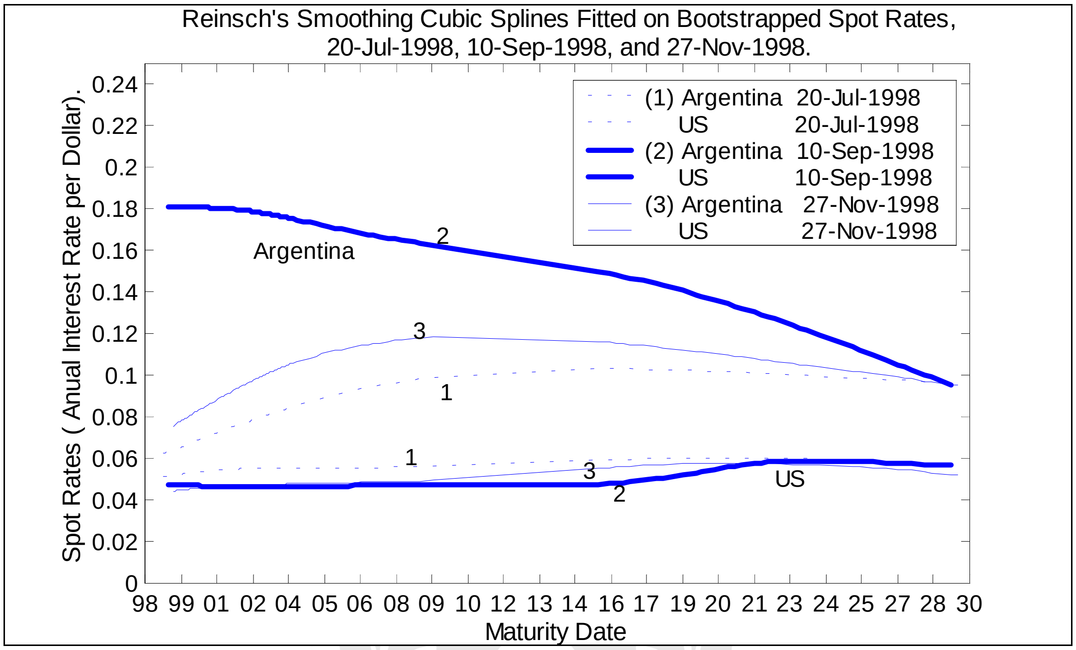
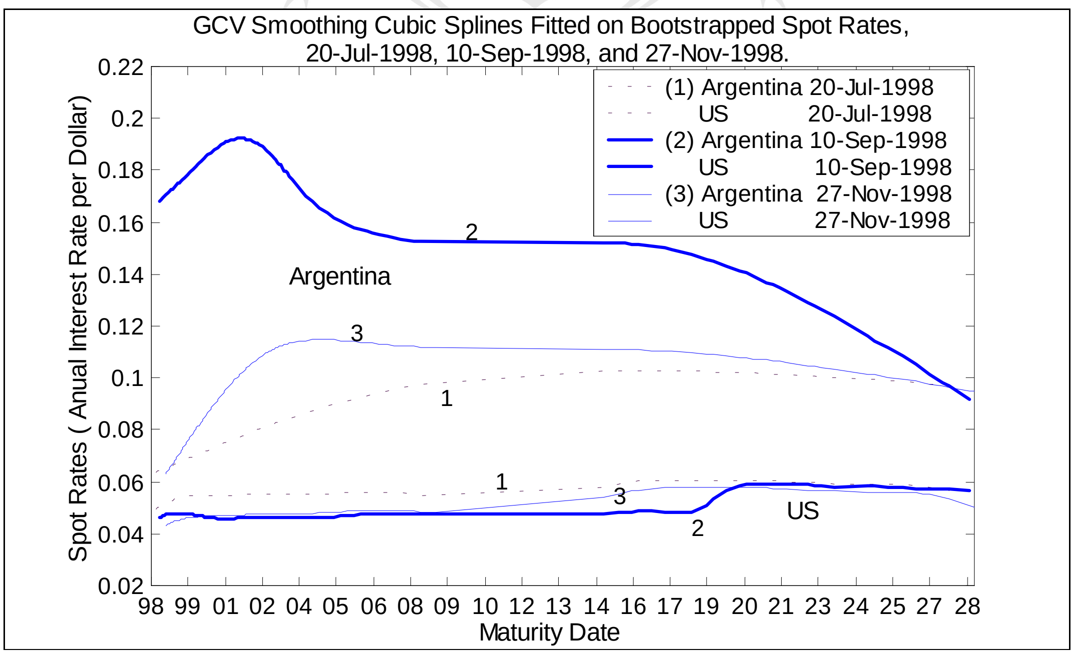


Figure 5.d.ii.



Looking at these figures, we can see that the Argentinean term structure suffered a significant change in its shape. Rates on short-term instruments increased significantly, while rates on long-term assets did not increase so much, making that the curve reversed. This means that individuals recognized the effects of this crisis as temporary. Maybe because of Asia's crisis lesson, or maybe because individuals rapidly noticed that Russia's economy had little to do with Argentinean one, individuals expected rates to go down relatively rapidly. After the crisis passed, interest rates went down to their original levels.

In this case, the Argentinean GCV splines resulted more variable than Reinsch's splines in the short-end, but more similar in the long end. Looking at U.S. term structure estimations, we see here also that these curves suffered a downward shift during the crisis, contrary to the upward shift that the Argentinean curves suffered. In consequence, this increased even more the spot rate spread between Argentinean government bonds and U.S. Treasuries.

5.e. The Brazilian Devaluation

Brazil is one of the world's most important economies, and clearly the most important in Latin America. As the Brazilian Government decided to devalue the Real in January 1999, many economies suffered a lack of credibility contagion, particularly Latin American emerging economies, such as Argentina. The inflationary and unstable Argentinean past was evidently not so far away, since international investors immediate reaction was to think that the next country to devalue its currency could be Argentina. The EMBI-Arg. index level reached 1,285 basic points in January 14th 1999, showing that the effects of this crisis were significantly more expensive for Argentina than the Asian crisis effects.

Figures 5.e.i. and 5.e.ii. show that the effects on Argentinean spot rates that the Brazilian devaluation caused during January 1999 where also seen as non-permanent effects. Looking at Reinsch's Argentinean splines, rates on short and medium term assets rose significantly, but long term rates did not suffered such changes. This gave the Argentinean curve a "humped" shape, but for 15th April 1999 it had already gone down to its previous level and shape. The GCV Argentinean spline fitted on spot rates at the peak of the crisis was downward sloping curve, because such spline showed higher values for short-term rates. This is a small difference, but shows how two different spline curves can result from changing the smoothing parameter.

Figure 5.e.i.

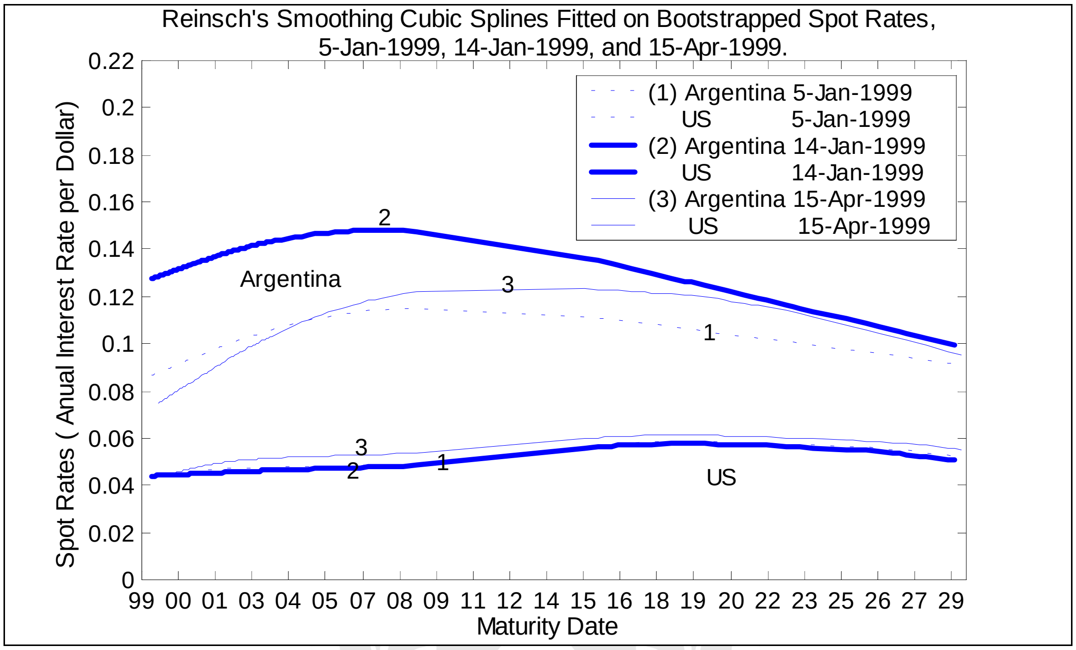
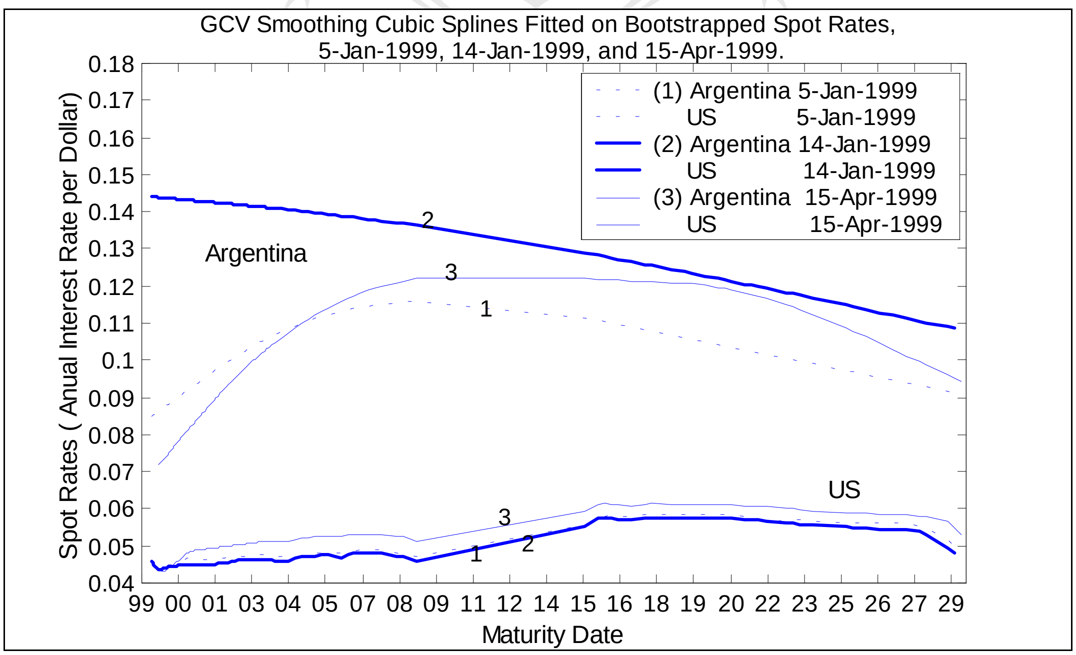


Figure 5.e.ii.



5.f. October 1999 President's Election Period

On October 24th 1999 Argentinean third President's election took place since democracy was reestablished in 1983, and Dr. Fernando de la Rua became Argentina's new elected president. His predecessor, Dr. Carlos Menem, had been president for 10 years, since 1989, been reelected in 1995. He had managed to transform Argentinean economy, though he failed in solving some important issues such as fiscal deficit and unemployment. The uncertainty on the new government's policies took country risk index to 1,205 basic points in July 20th 1999. To analyze how the election's results affected Argentina's term structure, we analyze the curves' shape on October 22nd 1999 vs. its shape on October 25th 1999.

Here, the two methods for choosing a smoothing parameter resulted into very similar spline functions too. The GCV Argentinean spline values showed a slightly bigger difference for medium term rates (though this was not bigger than 0.25%), because the October 22nd spline showed lower values, and the October 25th spline showed higher values, than using Reinsch's parameters. But in general, the splines from both methods resulted very similar.

As we can see, the President's election in Argentina did not have a significant effect on Argentinean term structure. Democratic institutions seem to be consolidated, and the President change was seen as a continuation of that country's development process, and not as a jump back to the pass.

<u>Figure 5.f.i.</u>

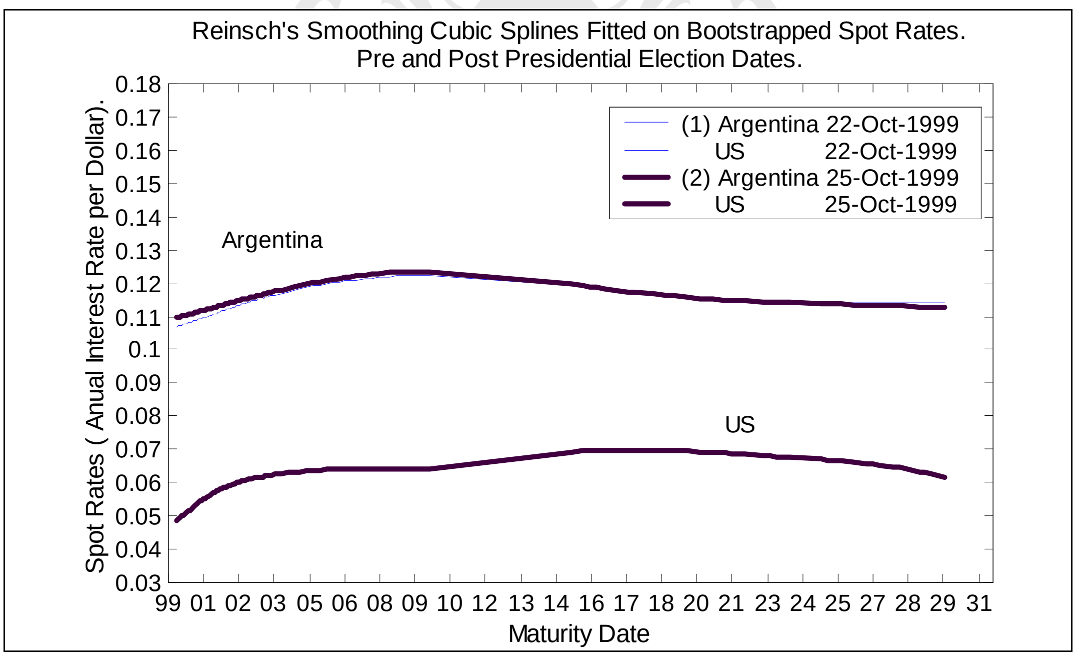
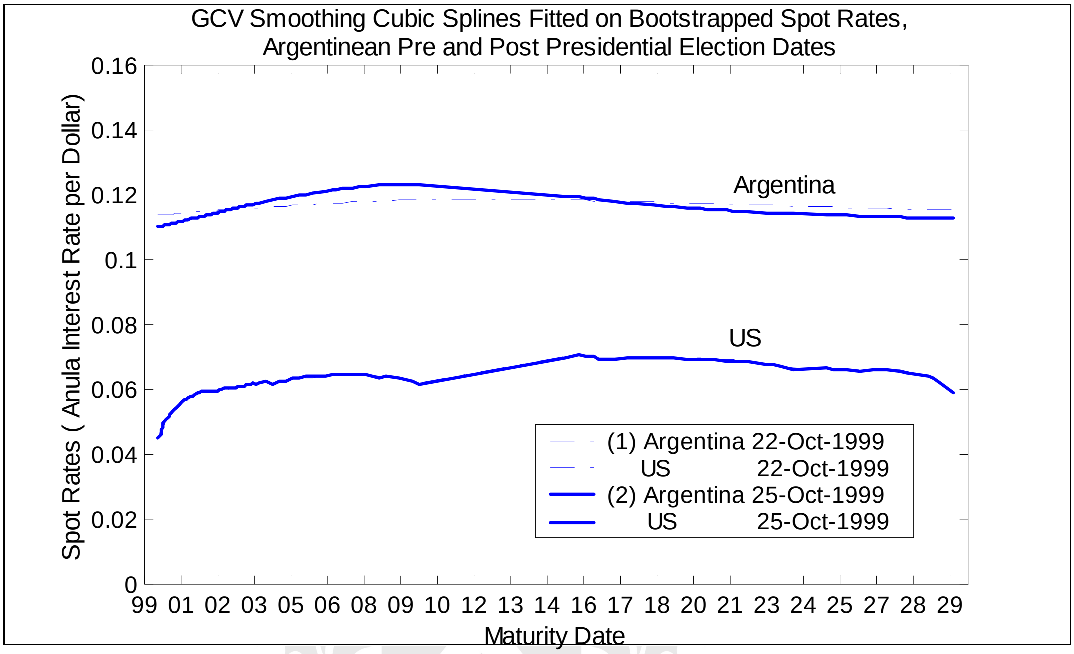


Figure 5.f.ii.



6.g. Comparing the Crises

In this work, we analyzed two important issues from the term structures we have estimated. First, the different shapes which these curves showed, where their variability, level and slope define that shape; and second, the spread between Argentinean and U.S. curves.

We found that Argentinean spot rates where much more variable than U.S. Treasury spot rates, making smoothing cubic splines particularly useful to get smoothed estimations of the Argentinean term structure curves. With respect to their levels, we found that all the crises increased Argentinean term structure levels, where the increase on short-term rates was generally bigger than the increase on long-term rates. Looking at the U.S. term structure, we observed that this did not suffer such big changes as the Argentinean curve. It even decreased during the Asian and the Russian crisis periods, making the spot rate spread between the two countries' curves even bigger. There was flight to quality.

With respect to their shapes and slopes, we found that in general Argentinean and U.S. term structures were upward sloping. But during some financial crisis periods, the Argentinean term structure reversed, because short-term rates increased much more than long term rates. This is the case of the "Tequila" and the Russian crises (and of the Brazilian devaluation period splines when we used the GCV smoothing parameter).

Figures 5.g.i and 5.g.ii. present the Argentinean term structures for those dates when the EMBI-Arg. index reached its peaks, and Tables 5.g.i. and 5.g.ii. present the values on those figures. We can see here how the different crises had different term structure effects. Note that the Mexican crisis peak curve is not included in these figures. As we already mentioned, we considered that this curve was not comparable with the other crisis peak curves for two reasons. First, the Tequila Mexican splines were fitted on yields to maturity, since only one Argentinean bullet security existed in those days. And second, they correspond to bonds which are not under the cross default regime, so their quality is not as good as the bonds we used for the other dates. In Tables 5.g.i. and 5.g.ii. we included that curve's values, but we suggest not comparing them with the rest, without considering the differences we mentioned.

Figure 5.g.i.

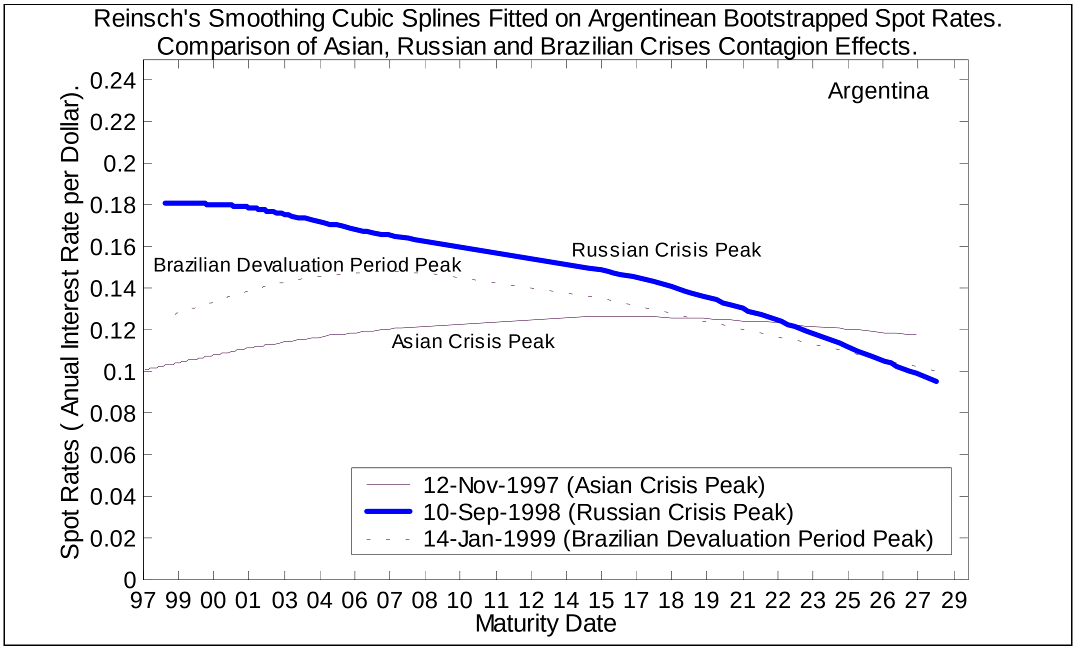


Figure 5.g.ii.

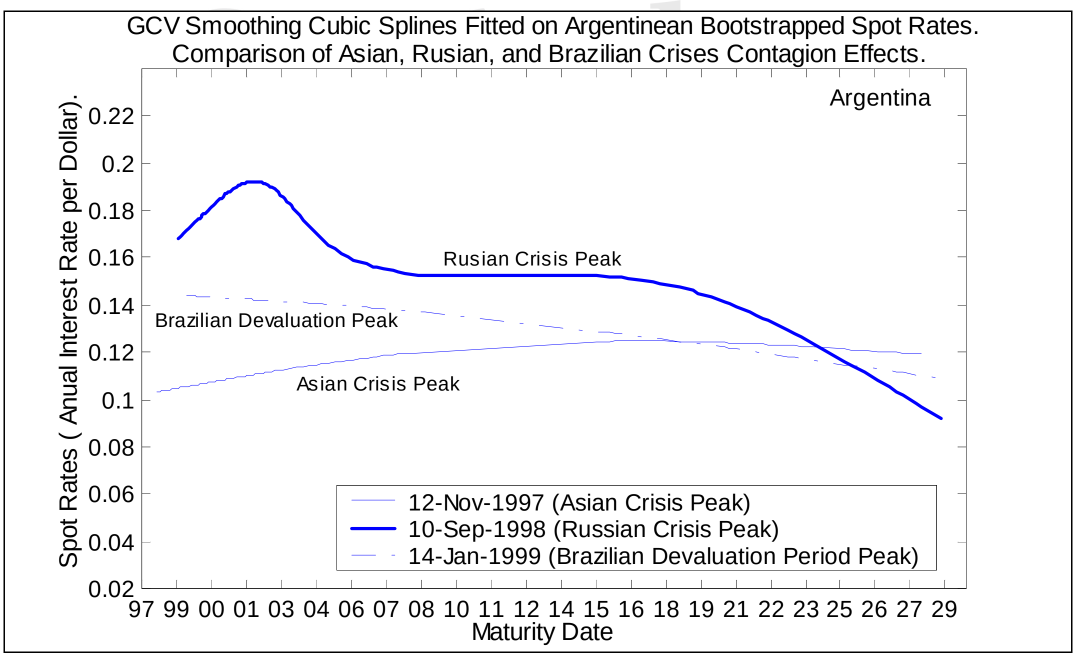


Table 5.g.i. Argentinean Term Structure Values at International Financial Crises Peaks using Reinsch's smoothing parameters. (In basic points).

	Years to Maturity						
Crisis	**1**	**5**	**10**	**15**	**20**	**25**	**30**
Asian Crisis Peak	1034	1153	1223	1261	1259	1219	1163
Brazilian Crisis Peak	1339	1470	1457	1351	1219	1085	950
Russian Crisis Peak	1810	1721	1610	1511	1361	1146	906
Tequila Mexican Crisis Peak	4561	3540	3132	--[30]	--	--	--

Table 5.g.ii. Argentinean Term Structure Values at International Financial Crises Peaks using GCV smoothing parameters. (In basic points).

	Years to Maturity						
Crisis	**1**	**5**	**10**	**15**	**20**	**25**	**30**
Asian Crisis Peak	1051	1143	1207	1242	1245	1221	1183
Brazilian Crisis Peak	1430	1394	1344	1283	1213	1137	1060
Russian Crisis Peak	1779	1650	1515	1525	1431	1173	852
Tequila Mexican Crisis Peak	4667	3452	3813	--	--	--	--

Second, with respect to the spread between Argentinean and U.S. curves we found that a significant spread existed during all dates we analyzed. And that this spread, suffered significant increases during the crisis periods. Naturally, it corresponds to the Argentinean government's credit risk, since we considered USD securities for both countries (therefore no currency risk is involved), and U.S. securities are considered credit risk free, as we already mentioned. Figure 5.g.iii. shows the spread differences on smoothing cubic splines for both countries, when the country risk index (EMBI-Arg.) reached its maximum level during the Asian, the Russian and the Brazilian crisis periods. The reader will note that the following figures are very similar to figures 5.g.i. and 5.g.ii., since as we already mentioned, the changes in the U.S. term structure splines were very small compared to the Argentinean ones. The tables show the values of the spread curves in both figures.

[30] As we already explained, during the "Tequila" Mexican crisis period, the Discount and the Par Brady bonds were the longest Argentinean government debt instruments. Their maturity is at 2007. As we said, these have U.S. Treasury warranty on their principal and two coupons payments, so we did not include them in group 2, which is the group we used for those dates. This caused that the resulting Argentinean term structure curves were shorter than the U.S. curves. The "---" in the tables mean that for those dates we did not count with Argentinean yield curve values.

Figure 5.g.iii.

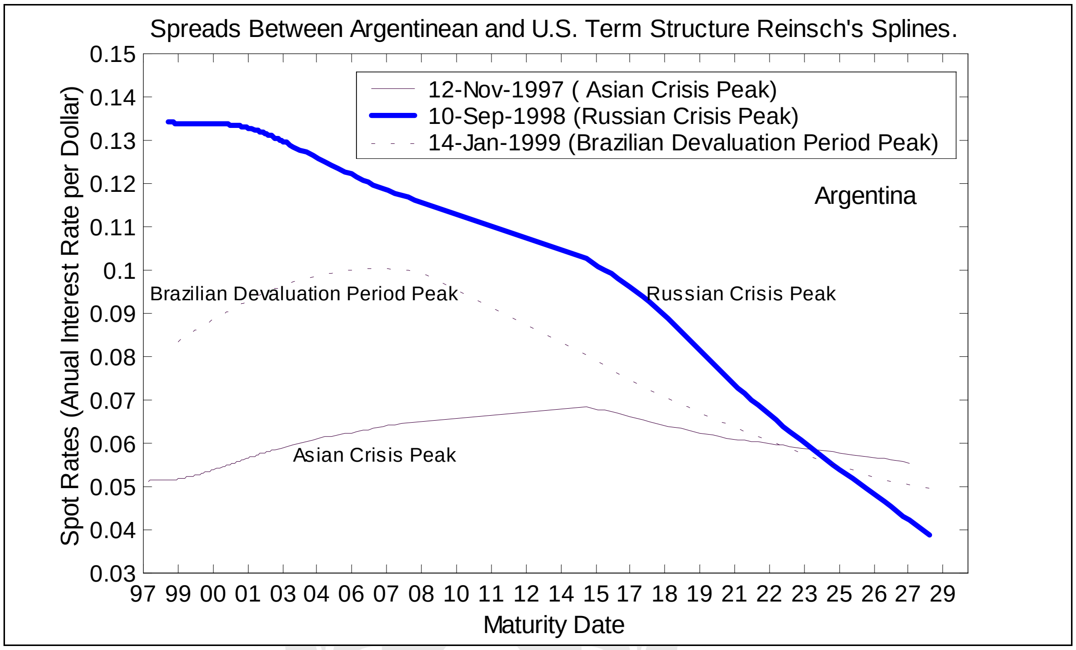


Figure 5.g.iv.

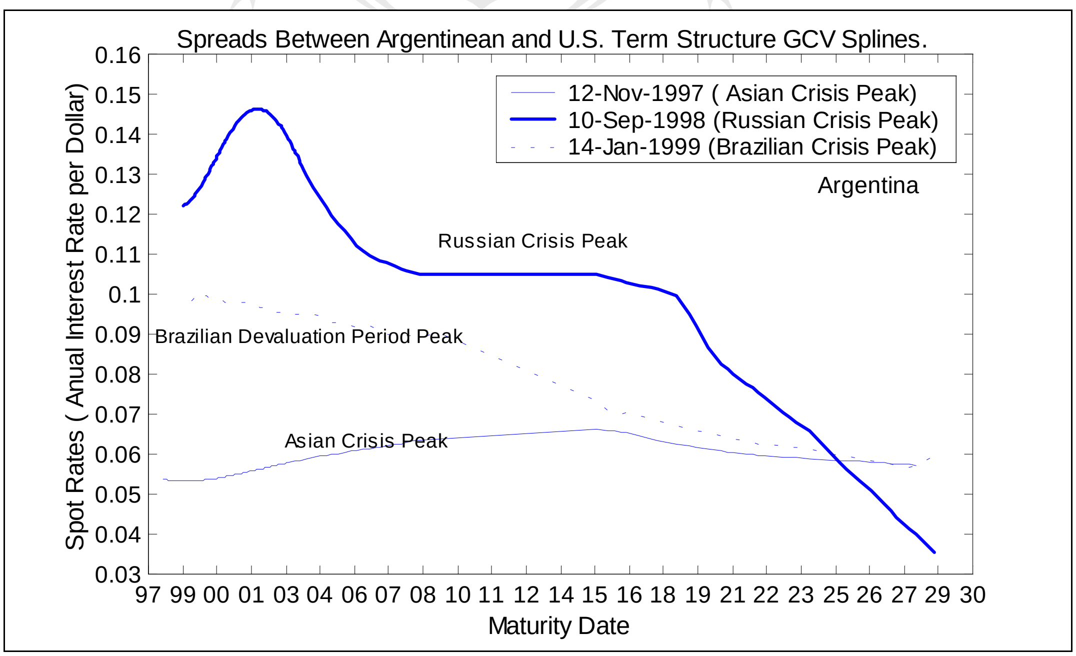


Table 5.g.iii. The Spreads between Argentinean and U.S. Term Structures at International Financial Crises Peaks using Reinsch's smoothing parameters (In basic points).

	Years to Maturity						
Crisis	**1**	**5**	**10**	**15**	**20**	**25**	**30**
Asian Crisis Peak	516	600	658	689	633	587	548
Brazilian Crisis Peak	890	998	954	788	646	538	471
Russian Crisis Peak	1340	1255	1140	1038	811	559	345
Tequila Mexican Crisis Peak	3925	2813	2382	--	--	--	--

Table 5.g.iv. The Spreads between Argentinean and U.S. Term Structures at International Financial Crises Peaks using GCV smoothing parameters (In basic points).

	Years to Maturity						
Crisis	**1**	**5**	**10**	**15**	**20**	**25**	**30**
Asian Crisis Peak	533	591	642	670	620	588	569
Brazilian Crisis Peak	980	918	906	709	639	590	788
Russian Crisis Peak	1303	1190	1044	1054	861	592	296
Tequila Mexican Crisis Peak	4019	2727	3071	--	--	--	--

6 Testing for Term Structure Significant Changes

To test in a rigorous manner if the term structure has significantly changed during those crises periods we will follow the spline test presented by Silverman (1985), based on Wahba (1983) previous results. This approach focuses first in obtaining inference regions for predicted values $\hat{g}_p(x_i)$ and then see if those intervals intersect each other. Silverman (1985), demonstrates in his article that the formula in equation (6.1) gives us a 95% confidence bands (CB) on the smoothing cubic spline that we estimated.

$$CB = \hat{g}_p(x_i) \pm 2.\hat{\sigma}.p^{-\frac{1}{8}}.\left(\sum w_i\right)^{-\frac{3}{8}}.2^{-\frac{3}{4}}.\hat{f}(x_i)^{-\frac{3}{8}} \qquad (6.1)$$

In other words, the confidence bands will contain all the data points that a certain spline is fitting, with a confidence interval of 95%. If two bands from different splines do not touch each other, the test says that the corresponding term structure splines are statistically different.

In equation (6.1), $\hat{\sigma}$ is the standard deviation of errors e_i, and therefore $\hat{\sigma}^2$ is the $Var(e_i)$. But this would not be the case if we would be considering different data weights in the model[31]. p is the smoothing parameter value used for the spline $\hat{g}_p(x_i)$, w_i are the data weights (which we set to $w_i=1$ for all i), and $\hat{f}(x_i)$ is the local density of the data points distribution at x_i. To calculate $\hat{f}(x_i)$, we grouped data points into equal sections according to their abscissa position, and calculated density by simply adding all data points in each group, and dividing that number by the total amount of data points.

Note that the method will calculate wider bands for splines with higher variance in the errors e_i, and smaller smoothing factor values. This is intuitively understandable, since wherever we have bigger variance in e_i, the band will necessarily have to be wider to contain 95% of the data, and wherever the smoothing factor value gets smaller, distance between observations and fitted splines gets bigger, and consequently, the bands will also have to be wider to contain 95% of the data points. The formula also includes the density distribution of data points. For regions with more data points, the bands will get narrower, and for regions with less data points, bands will get wider. Intuitively, we can say that for regions containing more data points, the band will not have to "worry too much" about distant observations. On the other hand, if data points are not numerous, the spline will consider more seriously each point.

We calculated confidence bands on splines using Reinsch's and generalized cross validation smoothing parameters. The confidence bands resulted too wide to discriminate among significant and not significant term structure changes under both methods, because the number of observations we are using was not big. Figures 6.a.i. and 6.a.ii. show an example of the confidence bands calculated on the Argentinean term structure estimated for October 22nd 1997 (this is the case were we had less observations (6), but we usually counted with more than 10). As we can see, this will obviously not identify significant changes in the curves.

[31] Silverman (1985) explains why if we consider different data weights, then σ^2 could be estimated by:

$$\hat{\sigma}^2 = \frac{\sum_{i=1}^{n}\{y_i - \hat{g}(x_i)\}^2}{n - tr(A(p))};$$

where tr(A(p)) is the trace of matrix A(n*n), which diagonal terms can be calculated as:

$$A(p)_{ii} = p^{-\frac{1}{4}}.n^{-\frac{3}{4}}.2^{-\frac{3}{2}}.\hat{f}(x_i)^{-\frac{3}{4}}$$

Figure 6.a.i.

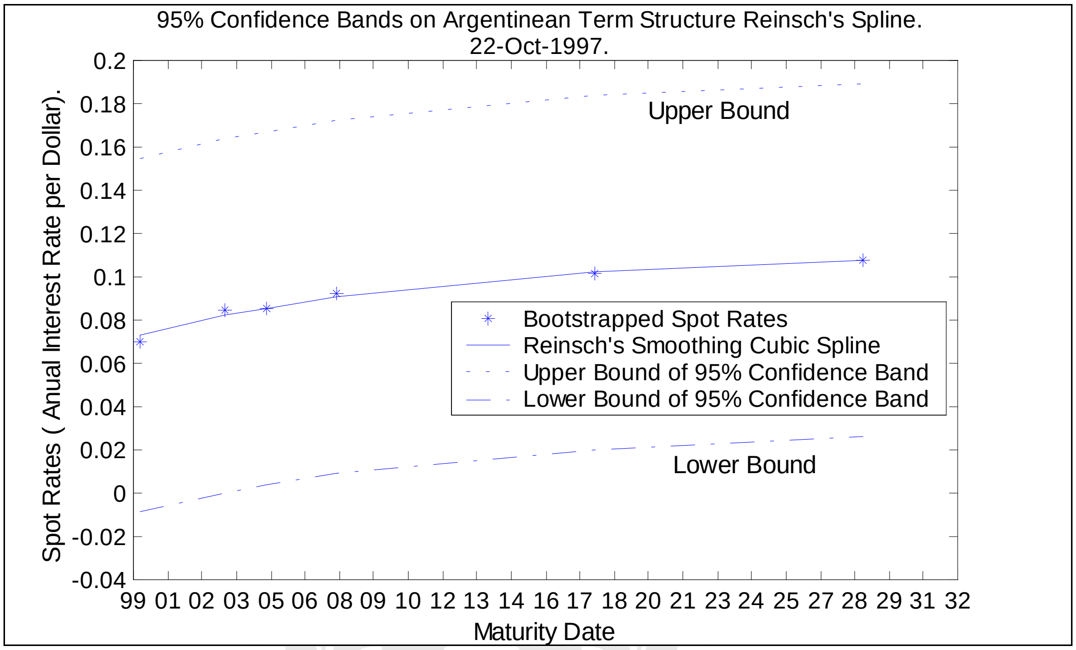
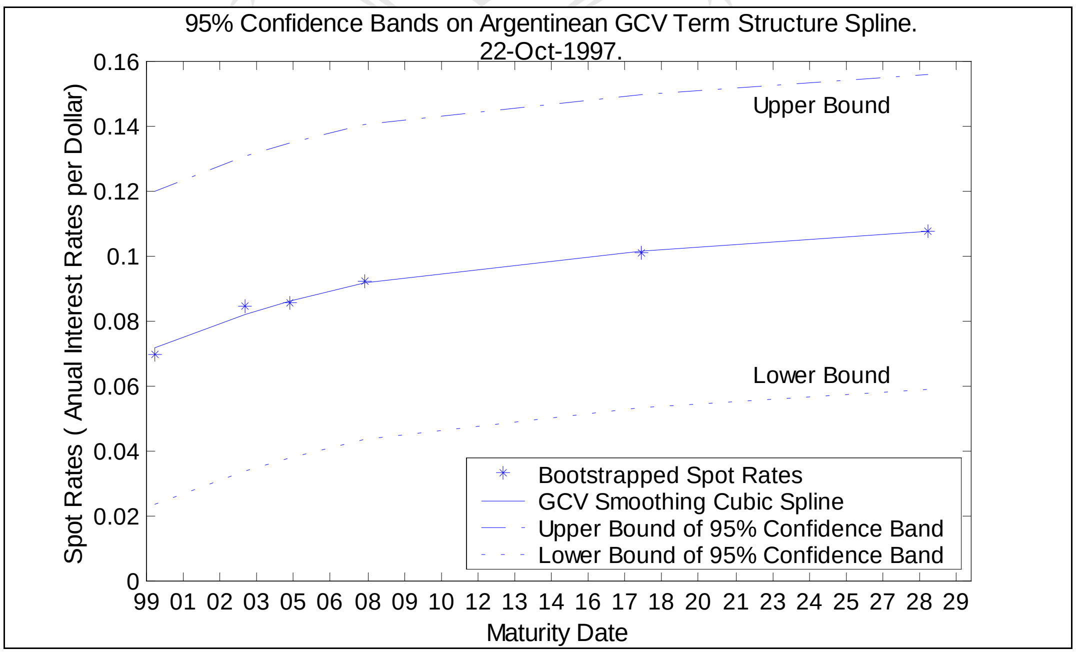


Figure 6.a.ii.



7 Conclusions

1) In this work we bootstrapped Argentinean and U.S. spot (or zero) rates from federal governments debt instruments, and fitted them with *smoothing cubic splines*, to estimate the term structure of interest rates for both countries. We found in splines a useful and efficient method to fit data, which can provide smooth but consistently related to the data functions. We applied both *generalized cross validation* and Reinsch's [(1967),(1971)] methods to choose the "optimal" value for the smoothing parameter in the splines, and we found that the resulting splines using both methods were very similar. We then applied a test for splines presented by Silverman (1985) based on Wahba's (1983) previous results.

2) We have found that the Argentinean term structure suffered big fluctuations, which were more important than the U.S. curves fluctuations, during international financial crisis periods. In general, Argentinean short-term rates suffered bigger increases than long-term rates during those periods. During the "Tequila" Mexican crisis and the Russian crisis periods, the upward shift on short-term rates was so big that Argentinean term structures reversed. During the Brazilian crisis period mainly medium-term rates suffered the biggest increases, resulting into a "humped" shaped term structure curve, when using Reinsch's smoothing parameter values. But using the GCV smoothing values, the term structure estimation showed higher values for short-term rates, resulting in a downward sloping curve too. Analyzing the Asian crisis period, we found that this crisis was the only one that caused a clear upward parallel shift in the Argentinean curve, causing that the term structure maintained a clear upward sloping shape at the peak of the crisis. Finally, we found that Argentinean 1999 president's election did not have an important effect on the term structure estimations for that country.

We also found that once the fundamentals that had originated the crises disappeared, the Argentinean term structure curves went down to their original levels and shapes. Hence, the contagion effects where only temporary.

Looking at the U.S. term structure estimations, we observed that the movements in these curves were much smaller than the movements in Argentinean curves as we already said. And even more, in some cases, for example during the Russian and the Asian crisis periods, these curves showed a clear downward movement, opposite to the movements in the Argentinean curves. There was flight to quality.

3) With respect to the spread between Argentinean and U.S. spot rates and yields to maturity, we observed that it showed high values during recent years. But, during international financial crisis periods, its values suffered significant increases, especially for short and medium term rates, caused by the upward shift of Argentinean short-term rates. The "Tequila" Mexican crisis was the one which generated higher spread values, then the Russian crisis, then the Brazilian devaluation, and finally the Asian crisis. That is the same order in the levels of the Argentinean term rises, since the U.S. term structure changes were very small compared to the Argentinean ones.

4) We then tested if those changes in level and shape where statistically significant or not, applying the test presented by Silverman (1985). This methodology calculates 95% confidence bands on splines, so that if bands from different splines touch each other for a certain maturity region, their difference cannot be said to be statistically significant for that maturity region. We calculated bands on splines that used Reinsch's and generalized cross validation smoothing parameter values, but we found that the resulting bands were excessively wide to detect significant changes, probably because the number of spot rates we counted with was not a big number.

5) Summarizing, the contagion effects that international financial crisis caused in Argentinean markets had bigger effects in that country's term structure than in U.S. term structure of interest rates, and these effects on Argentinean curves were much more important for short-term maturity rates than for long-term maturity rates. That is, in general, the crises caused in Argentinean curves bigger upward term structure shifts at short maturities than at long maturities, and once the crises were over, these curves went down to levels and shapes that were not significantly different to the levels and shapes that existed before the crises had begun. Hence, we conclude that the contagion effects suffered by Argentinean term structure of interest rates on government debt instruments were only temporary.

Statistical Appendixes

Appendix A. Argentinean Government Debt General Characteristics

This section presents data that can give us a general idea of Argentinean sovereign debt characteristics. Argentinean debt has been increased significantly during recent years. The following figure shows the different lenders, classified by maturity horizon. We see that Public Bonds represent the biggest percentage of Argentinean public debt.

Table A.1. Argentinean Public Debt by Lender and Maturity Horizon Outstanding as of September 30th 1999.

Lender	**Debt** Thousands of Arg$ (1Arg$ = 1 USD)
Medium & Long Term	**115,174,804**
Public Bonds	84,777,670
- Argentinean Pesos	6,574,074
- Foreign Currency	78,203,596
Loans	30,397,134
International Institutions	19,707,530
- BID	6,453,766
- BIRF	8,521,136
- FMI	4,698,277
- FONPLATA	26,691
- FIDA	7,660
Official Institutions	6,091,086
- Paris Club	3,338,312
- Other	2,752,774
Commercial Banks	3,961,092
Other	637,426
Short Term	**3,618,837**
Treasury Bills	3,618,837
Total	**118,793,641**

Source: Ministry of Economics of Argentina.
Http:\\www.mecon.gov.ar

If we classify debt by currency, we see that Argentinean debt is principally issued in U.S. dollars. Debt denominated in Euros, Argentinean pesos, and Japanese Yens are the other important currencies.

Table A.2. Argentinean Government Debt by Currency
Outstanding as of Sep 30th, 1999.

(Exchange rate as of 30/09/99 was 1 Arg$= 1 USD)

Currency	**%**
1. US Dollar	66.1%
2. Euro	19.6%
3. Argentinean Peso	6.6%
4. Japanese Yen	5.8%
5. Sterling Pound	0.9%
6. Swedish Frank	0.9%
7. Other currencies	0.1%
Total	**100%**

Source: Ministry of Economics of Argentina.
Http:\\www.mecon.gov.ar

A very important portion of Argentinean debt is issued on variable rates. This characteristic makes the Government very vulnerable to periods of international interest rate rises. In Table A.3., we see that more than 50% corresponds to debt paying variable rates.

Table A.3. Argentinean Government Debt by Interest Rate Type
Outstanding as of September 30th, 1999.

Interest Rate (Exchange Rate as of 30/09/99 was 1Arg$=1USD)	%
Fixed	**56.3%**
Variable	**43.7%**
- Libor	25.0%
- "Caja de Ahorro" Arg. Peso Deposits	4.9%
- FMI	4.2%
- On "Plazo Fijo" USD deposits (Survey BCRA*)	4.2%
- Other (BID, BIRF, Diverse)	5.4%
Total	**100%**

Source: Ministry of Economics of Argentina.
Http:\\www.mecon.gov.ar
(*) Interest rate informed by Argentina's Central Bank from daily survey on interest rates for bank savings in USD or in Arg$.

One of Argentinean government debt instruments most important characteristics are their heterogeneity. Figure A.4. shows the different types of instruments that the government has issued during recent years and the importance that these groups have.

Table A.4. The Different Series of Debt Instruments issued by Argentinean Government Outstanding as of September 30th, 1999. (In percentage.)

Foreign Currency Denominated Debt	**%**
Domestic Indebtedness	
Bonex	3.4%
Bocones	5.9%
Bontes	4.0%
Other	1.0%
External Indebtedness	
Brady Bonds	11.0%
Global Bonds	7.2%
Eurobonds	11.9%
Other	0.1%
Subtotal	44.5%
Argentinean Peso Denominated Debt	
Domestic Indebtedness	
Bocones	5.0%
Other	0.0%
External Indebtedness	
Global Bonds	0.4%
Other	0,1%
Subtotal	5.5%
Total	**100%**

Source: Ministry of Economics of Argentina.
Http:\\www.mecon.gov.ar

Appendix B. Argentinean Prices and Yields

Argentinean prices and yields to maturity where provided by M.A.E. S.A., I.A.M.C. S.A., and Mercado Abierto S.A., as we already explained. Now, if M.A.E. S.A. or I.A.M.C. S.A. provided prices and yields, then prices are presented in “real value” or “r.v.”. But, if Mercado Abierto S.A. provided them, then they are presented in “nominal value”.

With “nominal value” we refer to the price of 100 USD (or Arg.$) bond lamina. Suppose that the “residual value” (that part of a debt instrument’s principal that has not matured yet) was 50%. To find the “real value” of that debt instrument, if prices are published in “% by $100” or “nominal value” (n.v.), we would then have to multiply that nominal value by the “residual value” and divide it by $100. The real value corresponding to $90 (in % by 100) would then be $0.45, since as we explained, it can be solved from:

$100……………..………..…………0.50 (“residual value”)
$90 (n.v. or “nominal value”))…..……..(r.v.(“real value”))

Appendix C

Table C.1. USD and Argentinean Pesos Denominated Debt Instruments Issued since 1987.
Source: Ministry of Economics of Argentina.

	Group	Series	Maturity Date	Coupon Type	Bullet?	Currency
1	**"Bonos del Gobierno Nacional"**	BGO1	20/01/01	Floating	No	USD
2		BGO2	14/07/01	Floating	Yes	USD
3		BGO3	15/07/01	Floating	Yes	USD
4	**"Bonos Externos Globales"**	BOG X2	01/11/99	Fixed	Yes	USD
5	**("Globales")**	BOG X3	23/02/01	Fixed	Yes	USD
6		BOG X1	20/12/03	Fixed	Yes	USD
7		BOG X7	04/12/05	Fixed	Yes	USD
8		BOG X4	09/10/06	Fixed	Yes	USD
9		BOG X9	07/04/09	Fixed	Yes	USD
10		BOG X5	30/01/17	Fixed	Yes	USD
11		BOG X8	25/02/19	Fixed	Yes	USD
12		BOG X6	19/09/27	Fixed	Yes	USD
13	**"Bono de Cons.de Reg.de Hidroc."**	BOHI	02/12/08	Floating	No	USD
14	**"Bonos Externos"**	BONEX 87	07/09/97	Floating	No	USD
15	**("Bonex")**	BONEX 89	28/12/99	Floating	No	USD
16		BONEX 92	15/09/02	Floating	No	USD
17	**"Bonos del Tesoro"**	BOTE 5 (Bot1)	01/04/96	Floating	No	USD
18	**("Botes" and**	BOTE1	31/08/96	Floating	No	USD
19	**"Bontes")**	BOTE2	01/09/97	Floating	No	USD
20		BT 01	13/12/98	FIXED	Yes	USD
21		BOTE3	01/04/99	Floating	No	USD
22		BOTE10 (Bot2)	01/04/00	Floating	No	USD
23		BT 05	24/05/01	Fixed	Yes	USD
24		BT 02	09/05/02	Fixed	Yes	USD
25		BT 03	21/07/03	Floating	Yes	USD
26		BT 06	24/05/04	Fixed	Yes	USD
27		BT 04	19/09/27	Fixed	Yes	USD
28	**"Brady Bonds"**	FRB	31/03/05	Floating	No	USD
29	**("Bradies")**	DISCOUNT	31/03/23	Floating	No	USD
30		PAR	31/03/23	Fixed	Yes	USD

Appendix C

	Group	Series	Maturity Date	Coupon Type	Bullet?	Currency
31	**"Letras del Tesoro"**	LE 20	14/11/97	Zero Coupon	Yes	USD
32	**("Letes")**	LE 25	14/11/97	Zero Coupon	Yes	Arg $
33		LE 22	19/12/97	Zero Coupon	Yes	USD
34		LE 27	19/12/97	Zero Coupon	Yes	Arg $
35		LE 24	16/01/98	Zero Coupon	Yes	Arg $
36		LE 26	13/02/98	Zero Coupon	Yes	USD
37		LE 18	20/03/98	Zero Coupon	Yes	Arg $
38		LE30	20/03/98	Zero Coupon	Yes	USD
39		LE32	17/04/98	Zero Coupon	Yes	USD
40		LE29	15/05/98	Zero Coupon	Yes	USD
41		LE31	19/06/98	Zero Coupon	Yes	USD
42		LE33	17/07/98	Zero Coupon	Yes	USD
43		LE34	14/08/98	Zero Coupon	Yes	Arg $
44		LE 38	14/08/98	Zero Coupon	Yes	Arg $
45		LE 40	18/09/98	Zero Coupon	Yes	Arg $
46		LE 28	16/10/98	Zero Coupon	Yes	USD
47		LE 42	16/10/98	Zero Coupon	Yes	Arg $
48		LE 39	13/11/98	Zero Coupon	Yes	USD
49		LE 44	13/11/98	Zero Coupon	Yes	Arg $
50		LE 41	18/12/98	Zero Coupon	Yes	USD
51		LE 43	15/01/99	Zero Coupon	Yes	USD
52		LE 45	12/02/99	Zero Coupon	Yes	USD
53		LE 36	19/03/99	Zero Coupon	Yes	USD
54		LE 46	16/04/99	Zero Coupon	Yes	USD
55		LE 47	14/05/99	Zero Coupon	Yes	USD
56		LE 48	18/06/99	Zero Coupon	Yes	USD
57		LE 49	16/07/99	Zero Coupon	Yes	USD
58		LE 50	13/08/99	Zero Coupon	Yes	USD
59		LE 51	17/09/99	Zero Coupon	Yes	USD
60		LE 53	15/10/99	Zero Coupon	Yes	USD
61		LE 54	12/11/99	Zero Coupon	Yes	USD
62		LE 55	17/12/99	Zero Coupon	Yes	USD
63		LE 56	14/01/00	Zero Coupon	Yes	USD
64		LE 57	11/02/00	Zero Coupon	Yes	USD
65		LE 52	17/03/00	Zero Coupon	Yes	USD
66		LE 58	14/04/00	Zero Coupon	Yes	USD
67		LEX54	10/07/02	Zero Coupon	Yes	Arg $
68		LEX64	06/04/04	Floating	Yes	USD
69		LEX49	12/02/07	Zero Coupon	Yes	Arg $

	Group	Series	Maturity Date	Coupon Type	Bullet?	Currency
70	**"Bonos de Consolidación de**	PRE1	01/04/01	Floating	No	Arg $
71	**la Deuda Previsional"**	PRE2	01/04/01	Floating	No	USD
72	**("Bocones")**	PRE3	01/09/02	Floating	No	Arg $
73		PRE4	01/09/02	Floating	No	USD
74		PRO1	01/04/07	Floating	No	Arg $
75		PRO2	01/04/07	Floating	No	USD
76		PRO5	15/04/07	Floating	No	Arg $
77		PRO6	15/04/07	Floating	No	USD
78		PRO3	28/12/10	Floating	No	Arg $
79		PRO4	28/12/10	Floating	No	USD
80	**"Bono República Argentina"**	SPAN	30/11/02	Floating	Yes	USD
81	**"Bonos República Argentina A Tasa Variable"**	FRAN	10/04/05	Floating	Yes	USD
82	**"Ferrobonos"**	FERR	Perpetuity	Floating	No	USD
83	**"New Money Bonds"**	NMB	25/10/99	Floating	No	USD
84	**"Spanish Bonds"**	ESP	31/03/08	Floating	No	USD
85	**"Floating Rate Bond 06 "**	FRB06	02/03/06	Floating	No	USD
86	**"Bonos de Inversion y**	BIC1	28/12/99	Floating	No	USD
87	**Crecimiento"**	BIC5	01/05/01	Floating	No	USD
88	**"Bonos de la Tesoreria"**	TESA	01/04/96	Floating	No	USD
89		TESB	01/04/00	Floating	No	USD
90	**"Bocep"**	Bocep	Various	Zero Coupon	No	Arg $

Appendix D. Fitting Yield Curves with Smoothing Cubic Splines

This section shows our results on fitting smoothing splines on yields to maturity instead of doing so on bootstrapped spot rates, using Reinsch's smoothing parameter values. As we explained in section 4, we do this so that we can include Argentinean non-bullet government debt instruments into the analysis, since the Matlab routines can not bootstrap spot rates out of non-bullet debt instruments information.

We divided Argentinean government's debt instrument (issued in USD) into group 1 and group 2. The first group includes those that are under the cross default regime. The second group includes those that are not under that regime. The longest security in the second group matures in the year 2007, and that is why the yield curve on this group is shorter than the one fitted on the securities from the first group. As we also mentioned in section 4, we did not fitted splines on yields from Argentinean bonds issued in Argentinean pesos because the number of observations was too small. With respect to the two Argentinean securities counting with U.S. Treasury warranty on their payments (PAR and Discount), we did not include them in any of the groups, because their quality is considered to be better than all the rest. We could not, obviously, fit separate splines on their rates, because these are only two.

During the "Tequila" crisis period, only one Argentinean bullet debt instrument existed in group 1, so in section 4 we fitted splines on yields corresponding to instruments in group 2 for this period. We do not show those figures again in this appendix.

U.S. treasuries usually have coincident maturity dates. That is, it is normal that more than one debt instrument mature at a given day. Unfortunately, the Matlab function which plots smoothing cubic splines requires that the dates (or 'x') series be strictly increasing, and therefore it would not be able to fit a spline wherever two rates have the same maturity date. This was not a problem when we fitted spot rates, since once we run the bootstrapping Matlab function which calculates the spot rates, it would give us two series as output: the maturity dates, and the spot rates. Those maturity dates were strictly increasing, allowing us to fit the smoothing splines. That is the reason why the U.S. curves which appear in this appendix are splines fitted on spot rates[32].

[32] Only two Argentinean government's debt instruments (from the ones we are considering) had equal maturity dates. In order that the Matlab function which plots smoothing cubic splines allowed us to fit yields to maturity on Argentinean debt instruments for the dates in which those two traded (the dates in which they coincided where only a few), we saw three solutions: take one of them out of the sample, calculate an average on the yields that these two were offering (which would reduce the number of observations too), or change for only one day the maturity date of one of them. We chose the third option because we saw that one day in a 30 years curve would not have a significant effect, and in that way the number of observations would not be reduced.

Figure D.1. The Asian Crisis

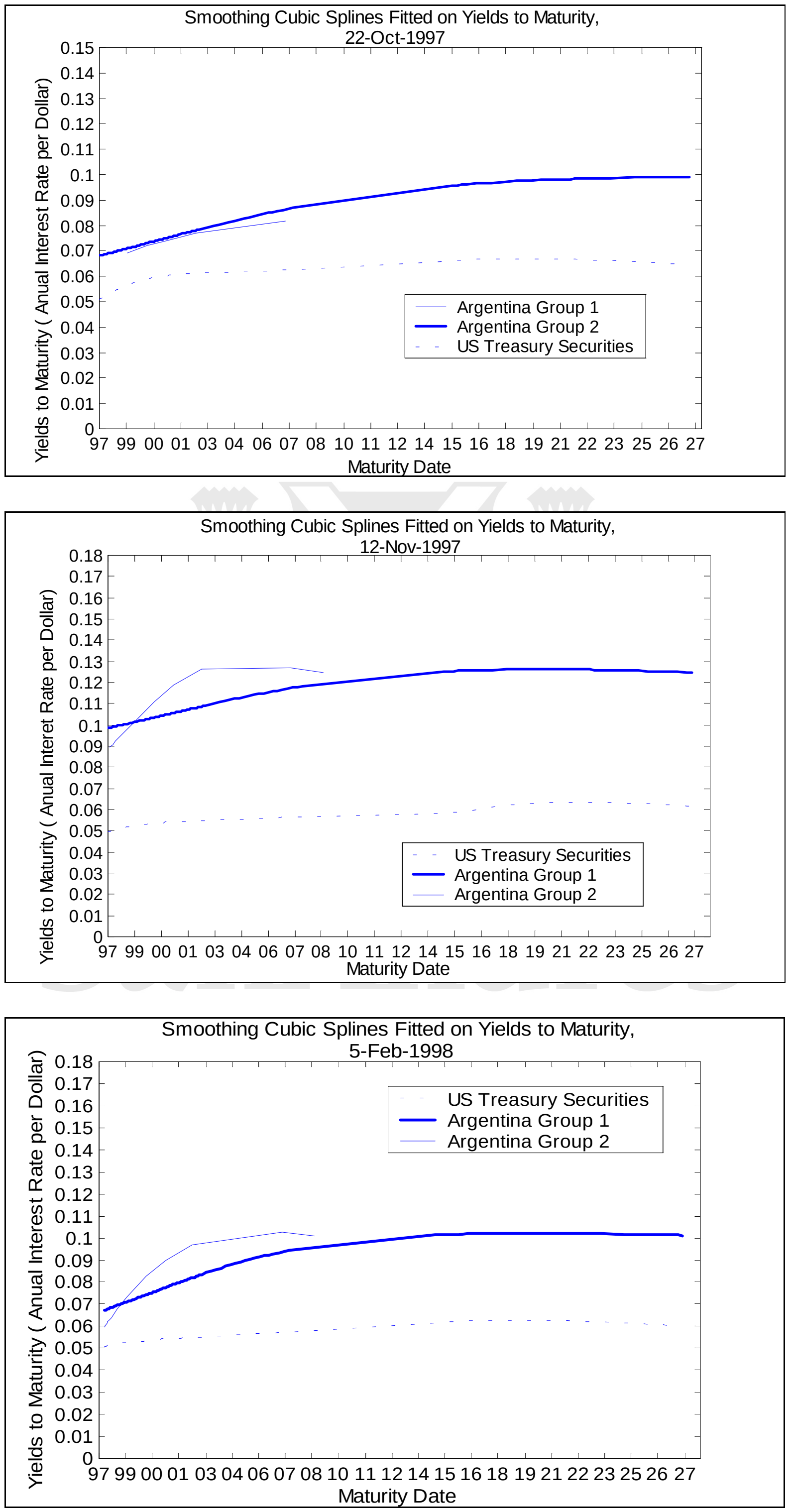


Figure D.2. The Russian Financial Crisis

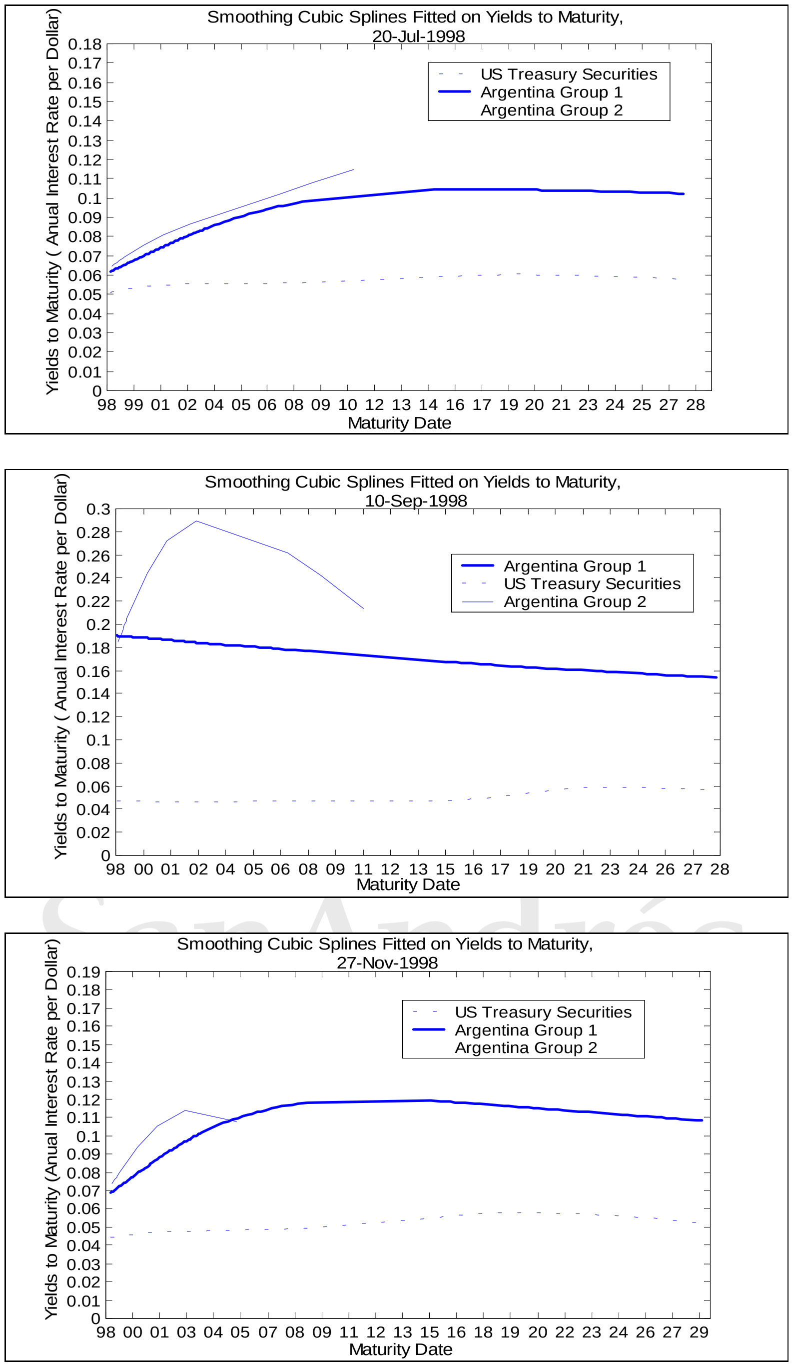
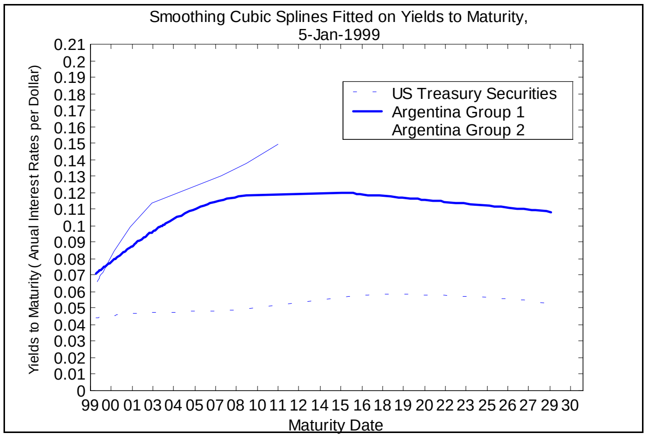
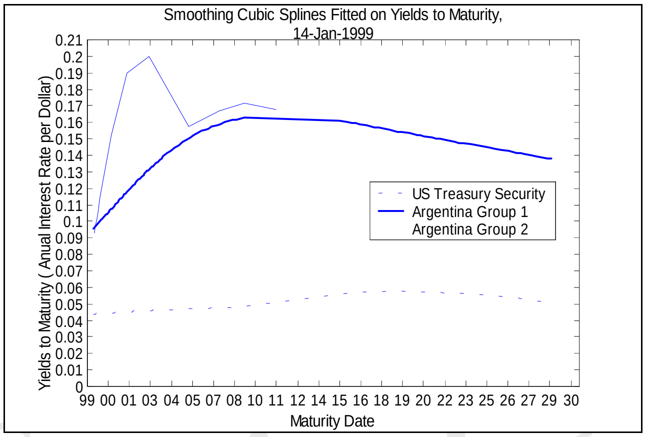


Figure D.3. The Brazilian Devaluation Period





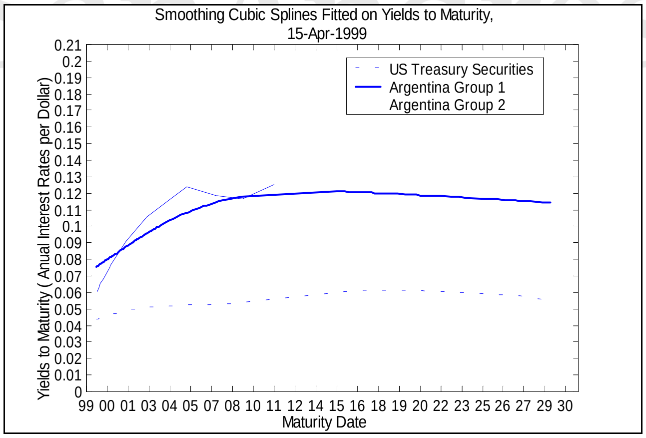
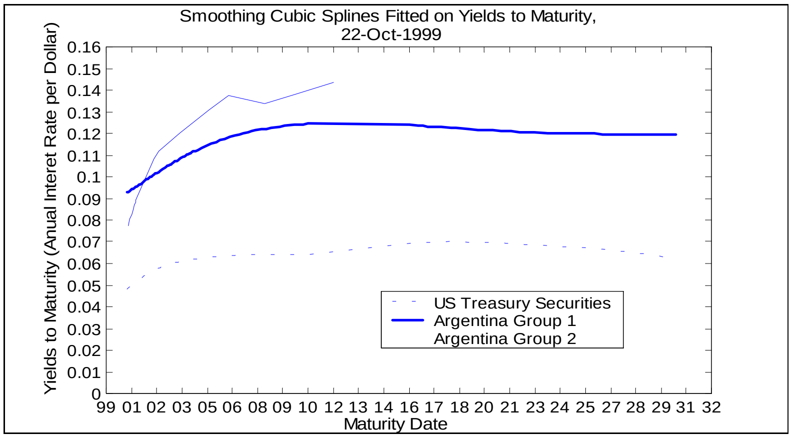
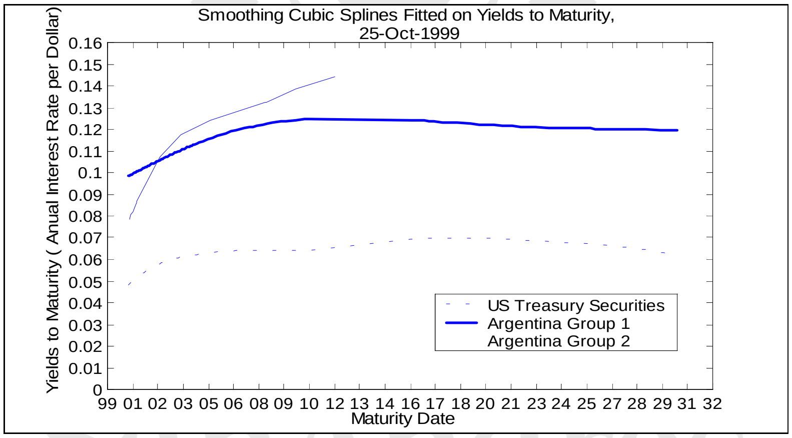


Figure D.4. Argentina's President Election Dates

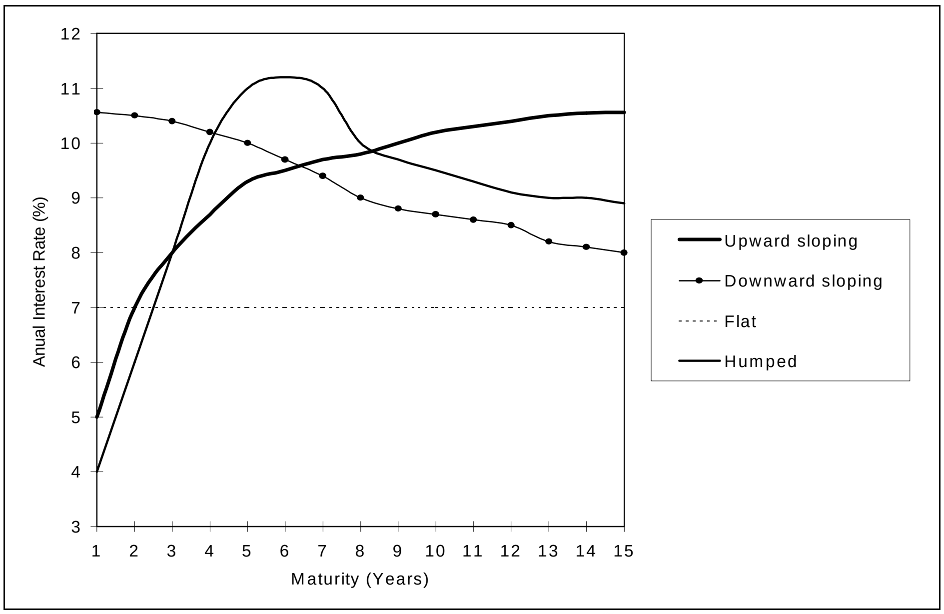




Appendix E. The Determinants of the Term Structure Shape

In this appendix we mention some of the most important theories that have been proposed to explain the varying shapes of the term structure of interest rates. Almost any shape is possible to be found for this curve, but there are four shapes that are very common. Figure E.1. illustrates these four shapes.

<u>Figure E.1.</u> The four most common term structure shapes. An example.



Many hypotheses have been postulated to understand these shapes, but they can be separated into two major groups: the *expectations hypothesis*, and, the *market segmentation hypothesis*[33].

The *pure expectations hypothesis* states that the forward rates exclusively represent the expected future rates and that investors think and choose their assets in a rational way, without any maturity preference. For example, if the market is expecting interest rates to grow, demand for long term assets will fall because investors will put their money on short term assets so that they can then re-invest that money at higher rates. As demand on long term assets falls, their prices will fall, increasing long term rates. But to this theory we should add some considerations known as *risks premiums* that investors surely consider.

For example, it is known that bond price volatility increases with maturity, very fast for short-term assets, but at a continuously decreasing rate for longer term assets. Therefore, investors would not be willing to bear this *liquidity risk or price risk* unless higher returns are

[33] This appendix is based on concepts presented more extensively in <u>The handbook of fixed income securities</u>, Fabozzi, 1997, or in <u>Investments</u>, Bodie, Kane and Markus, 1996.

offered to compensate that risk. The term structure would then represent both future expectations and an extra return increasing on maturity, called *price-risk premium*. Another example is the *re-investment rate risk*. Re-investment rate risk is associated with future interest rates uncertainty. For example, a short-term asset may offer a higher short-term return, but the long-term investor is not sure he will be able to reinvest his earnings at the same rate when the short-term asset matures. Choosing a long-term asset the re-investment risk is eliminated, so short-term assets should offer a *premium* to attract investors who do not want to bear this risk. Finally, the *habitat preference hypothesis* states that investors have preferences with respect to the maturity of the assets. To take an investor out of it's preferred habitat, a premium should exist, positive or negative, representing the investor's aversion to either short or long-term investments. These would cause that not only the future rate expectations determine the assets' market price, but also the forces within the short and the long term markets.

On the other hand, the *market segmentation hypothesis* states that investors are divided in two major groups according to their maturity preferences: short and long term investors. But now the offer and demand within each market will solely determine the assets' prices. According to this hypothesis, the markets are segmented. Commercial banks are usually the principal investors on short-term assets, while pension funds are the clearest examples for long term investors. . Therefore, according to this theory, the only determinants for the term structure shape are the market's supply and demand forces within each group. This is implying that once investors have decided their investment horizon, they will not change such horizon to take advantage of an arbitrage opportunity in the market. This view of the market is not common today, since both borrowers and lenders seem to compare long and short-term rates, before deciding which asset to buy or to sell.

Bibliography

• Bates D., Linstrom G., Wahba G., and Yandell B., "GCVPACK-Routines for Generalized Cross Validation", UW-Madison Statistics Dept TR, 775 (Rev), Oct1986.

• Bing-Huei, Lin, "Fitting the term structure of interest rates for Taiwanese government bonds", Journal of Multinational Financial Management, Volume 9, Issue 3-4, November 1999.

• Bodie, Z., Kane, A., and Marcus, A., Investments, 5th ed., Irwin McGraw-Hill, 1996.

• Caio Ibsen Rodrigues de Almeida, Antonio Marcos Duarte Jr., and Cristiano Augusto Coelho Fernandez, "Decomposing and simulating the movements of term structure of interest rates in emerging Eurobond markets", The Journal of Fixed Income, June 1998.

• Craven P., and Wahba, G., "Smoothing noisy data with spline functions", Numerische Mathematik, 1979, 31, pp. 377-403.

• Dabós, Marcelo, and Gómez Mera, Laura, "The Tequila Banking Crisis in Argentina", Chapter 9 in International Banking Crises, Benton E. Gup (ed.), Quorum Books, Westport, Connecticut.London, 1999.

• De Boor, C., "A practical guide to splines", Applied Mathematical Sciences, Vol. 27, Springer- Verlag, New York (1978).

• Dyn, S., "Credit risk analysis for developing country bond portfolios", The Journal of Portfolio Management, Winter 1997.

• Dirección de Administración de la Deuda Pública, Condiciones de Emisión de los Títulos de Deuda Argentina, National Ministry of Economics, Argentina, 1999.

• Duff & Phelps Credit Rating Co., Rating Guide, May 1999.

• Erisman A.M. and Tinney W.F., "On computing certain elements of the inverse of a sparse matrix", Communications of the ACM, 1975, 18(3), 177-179.

• Fabozzi, F. ed., The Handbook of Fixed Income Securities, 4th ed. McGraw-Hill, 1997.

• Fabozzi, F., Advanced Fixed Income Portfolio Management, IRWIN, 1994.

• Ferguson Robert and Raymar Steven, "A comparative analysis of several popular term structure estimation models", The Journal of Fixed Income, March 1998.

• Fisher, Nychka and Zervos, "Fitting the term structure of interest rates with smoothing splines", Finance and Economics Discussion Series, Division of Research and Statistics, Division of Monetary Affairs, Federal Reserve Board, Washington D.C., January 1995.

• Gonzalez, J., Spencer, R., Walz, D., "The information in the Mexican term structure of interest rates: capital market implications", Journal of International Financial Markets, Institutions & Money, Volume 9, Issue 2, April 1999.

• Greville, T.N.E. (ed.), "Theory and application of spline functions", New York: Academic Press, 1969.

• Gup, Benton E. (ed.), International Banking Crises, Quorum Books, Westport, Connecticut.London, 1999.

• Hutchinson M.F and De Hoog F.R., "Smoothing noisy data with spline functions", Numerische Mathematik, 1985, 47(1), pp. 99-106.

• Hutchinson M.F., Subroutine CUBGCV, CSIRO Division of Mathematics and Statistics, 1985, Canberra, ACT 2601, Australia, P.O. Box 1965.

• Instituto Argentino de Mercado de Capitales-Mercado de Valores de Buenos Aires S.A., Análisis de Bonos, Buenos Aires, Argentina, 1996.

• International Monetary Fund, World Economic Outlook-Interim Assessment, December 1997.

• International Monetary Fund, World Economic Outlook-Interim Assessment, December 1998.

• Ilmannen, A.; and Iwanowski, R.; "Dynamics of the shape of the yield curve", The Journal of Fixed Income, September 1997.

• Lyche T., Schumaker L.L., and Sepehrnoori K., Fortran subroutines for computing smoothing and interpolating natural splines, Advances in Engineering Software, 1983, 5(1), 2-5.

• MatLab Version 5.3.0.10183 (R11).

• MatLab Toolboxes
  Financial Toolbox Version 2.0.1 (R11).
  MATLAB Tour Version 1.2 (R11).
  Optimization Toolbox Version 2.0 (R11).
  Spline Toolbox Version 2.0.1 (R11).
  Statistics Toolbox Version 2.2 (R11).

• MatLab Toolbox User's Guides (for Version 5.3 (R11)), The MathWorks Inc.
  Matlab Excel Link Toolbox User's Guide, The MathWorks Inc., 1999.
  Matlab Financial Toolbox User's Guide, The MathWorks Inc., 1999.
  Matlab Statistics Toolbox User's Guide, The MathWorks Inc., 1999
  Matlab Spline Toolbox User's Guide, by Carl de Boor and The MathWorks Inc., 1999.

• Mercado de Valores de Buenos Aires S.A., Boletín Semanal de la Bolsa de Comercio de Buenos Aires, Several Volumes.

• McCulloch, J. Huston. "An estimate of the liquidity premium", Journal of Political Economy, 1975, pp. 95-118.

• McCulloch, J. Huston. "Measuring the term structure of interest rates", Journal of Business, January 1971, pp. 19-31.

• McCulloch, J. Huston. "The tax adjusted yield curve", Journal of Finance, 1975, pp. 811-830.

• Reina, Anthony, Matlab MEX interface for GCVSPL and SPLDER, (based on Dwight Meglan's C code), April 1998. Available at Http://isb.ri.ccf.org/software/sigproc.html

• Reinsch, C., "Smoothing by spline functions", Numerische Mathematik, 1967, 10, pp.177-183.

• Reinsch, C., "Smoothing by spline functions II", Numerische Mathematik, 1971, 16, pp.451-454.

• Roberds, W., and Whiteman, Charles, "Endogenous term premia and anomalies in the term structure of interest rates: Explaining the predictability smile", Journal of Monetary Economics, Volume 44, Issue 3, December 1999.

• Silverman, B.W., "Some aspects of the spline smoothing approach to non-parametric regression curve fitting", J.R.Statistic Society, 1985, 47, N° 1, pp. 1-52.

• Standard & Poor's, Calificaciones y Fundamentos, June 1999.

• The Math Works Inc., "Deriving and fitting interest rate curves using matlab and the financial toolbox", 1998.

• The New York Times, several publications.

• Utreras, F., "Un paquete de programas para ajustar curvas mediante funciones spline", Technical report MA-80-B-209, Mathematics Department, Universidad de Chile, Santiago, 1980.

• Vandersteel, Tina, "Emerging Markets Bonds Index Plus ($EMBI^+$): Methodology", Emerging Markets Research, J.P.Morgan Securities Inc., New York, 12 July 1995.

• Vasicek, O. and Gifford Fong, H., "Term structure modeling using exponential cubic splines", The Journal of Finance, Vol XXXVII, No 2, May 1982.

• Waggoner, D., "Spline methods for extracting interest rate curves from coupon bond prices", Federal Reserve Bank of Atlanta, Working Paper 97-10, November 1997.

• Wahba, G., "Smoothing noisy data with spline functions", Numerische Mathematik, 1975, 24, 383-393.

• Wahba, G., " A completely automatic French curve: fitting spline functions by cross-validation", Communications in Statistics, 1975, 4, pp. 1-17.

• Wahba, G., "Improper priors, spline smoothing, and the problem of guarding against model errors in regression", J.R.Statistic Society, 1978, b 49, pp. 364-372.

• Wahba, G., "How to smooth curves and surfaces with splines and cross-validation", Proceedings of the 24th conference of the design of experiments, U.S. Army Research Office, Report 79-2, 1979.

• Wahba, G., "Numerical and statistical methods for mildly, moderately and severely ill-posed problems with noisy data", Technical report N°:595, Department of Statistics, University of Madison (WI), February 1980.

• Wahba, G., "Bayesian confidence intervals for the cross validated smoothing spline", J.R.Statistic Society, 1983, B 45, pp.133-150.

• Wahba, G. and Wendelberger J., "Some new mathematical methods for variational objective analysis using splines and cross validation", Monthly Weather Review, 1980, 108, pp. 36-57.

• Wegman, E. and Wright, I., "Splines in statistics", Journal of the American Statistical Association, June 1983, Volume 78, Number 382, Theory and Methods Section.

• Wegman, E., and Wright I., "Splines in Statistics", Journal of American Statistical Association, June 1983, Volume 78, Number 382, Theory and Methods Section.

• Wittaker, E., "On a new method of graduation", Proc. Edinburgh Mathematics Society, 1923,N° 41, pp. 63-75.

• Woltring Herman J., "A FORTRAN package for generalized cross-validatory spline smoothing and differentiation", Advances in Engineering Software, 1986, 8(2): 104-113.

• Woltring, Herman J., GCVSPL Fortran package for spline smoothing and differentiation, Philips Medical Systems Division, Eindhoven, University of Nijmegen, The Netherlands, 1986. Available at Http://www.netlib.com.

• Yao, Yong, "Term structure modeling and asymptotic long rate", Insurance: mathematics and Economics, Volume 25, Issue 3, December 1999.