DOCUMENT DE TREBALL

XREAP2018-5

ALTERNATIVE METHODS OF ESTIMATING THE LONGEVITY RISK

Catalina Bolancé (RISKCENTER, XREAP)
Montserrat Guillén (RISKCENTER, XREAP)
Arelly Ornelas (RISKCENTER, XREAP)

Alternative methods of estimating the longevity risk

Catalina Bolancé, Montserrat Guillén and Arelly Ornelas
Department of Econometrics, Riskcenter-IREA, University of Barcelona,
Av. Diagonal, 690, 08034 Barcelona, Spain

October 4, 2018

Abstract

The aim of this paper is to estimate the longevity risk and its trend according to the age of the individual. We focus on individuals over 65. We use the value-at-risk to measure the longevity risk. We have proposed the use of an alternative methodology based on the estimation of the truncated cumulative distribution function and the quantiles. We apply a robust estimation method for fitting parametric distributions. Finally, we compare parametric and nonparametric estimations of longevity risk.
Keywords: longevity, value-at-risk, nonparametric inference.

1 Introduction

Human Mortality has experienced a substantial decrease during the 20th century. This mortality reduction directly affects all the schemes based on life expectancy, e.g. population and economic policies, pension and dependency regimes and health schemes, among others.

The relation between mortality and life expectancy is obvious; if mortality decreases life expectancy increases. Life expectancy could be defined as the average time in years that a person is expected to live. There is no certainty about the maximum age that an individual could attain; longevity, therefore, is considered a risk in some scenarios where increased longevity could causes significant economic losses. For example, financial and insurance companies should be worried about longevity; premiums in life insurance or annuities in pension plans are directly affected by the age of death. Furthermore, companies are increasingly looking for more accurate risk estimates. For example, in the case of insurances associated with longevity, note that although the age usually is measured in years, it is a continuous variable. To improve the accuracy of risk estimation, the companies need to have models that allow them to interpolate accurately all values of the distribution of the variable, beyond the sample information. We are interested in evaluating the risk of an individual surviving beyond the standard prevision.

It is considered that 65 is the age of retirement. The aim of this paper is to estimate the longevity risk according to the age of the individual. For estimating longevity risk we need to fit the distribution of the variable age of death given that the individual is alive at age $a \geq 65$. We compare the results obtained using parametric and nonparametric method with the method proposed by Alemany et al. (2013). The latter method has also been extended in this paper.

For evaluating the longevity risk beyond age 65 we apply the concept of value-at-risk at α confidence level (VaR_α), where α is a probability near 1, to the variable that measures lifetime duration. The VaR_α is commonly used to assess monetary losses. Longevity is not a monetary loss, but it is a risk, because it is directly related to activities that involve higher expenses when people get older. In order to measure the degree of aging of a population, the idea is to quantify the maximum number of years that a small fraction of the population could survive. Precisely, the VaR_α reflects the number of years that only a small $(1-\alpha)\%$ fraction of the population survives. In Ornelas et al. (2013) longevity risk has been analysed under a parametric theory. These authors fitted a Weibull distribution to the lifetime duration variable and concluded that there were large gender differences.

Some authors, for instance Kannisto (2000) and Cheung et al. (2005), have observed that lifespan has increased more slowly in some populations, this phenomenon is called mortality compression (see, Fries, 1980). This means that the age interval, where the number of deaths are concentrated, has remained almost unchanged in recent years. In contrast, Yue (2011) has shown that mortality improvements are not slowing down; on the contrary, mortality at old ages will continue decreasing in the near future. There is no absolute truth about life boundaries. The uncertainty of the future leads to the need of evaluating the longevity risk.

For example, in the Mexican population the percentage of men aged 80 and more has grown from 0.92% in 2000 to 1.21% in 2010, which represents an increment of 53%. With respect to women, the percentage has grown from 1.13% in 2000 to 1.49% in 2010, representing an increment of 54%.

The shape of the distribution associated with the variable lifetime duration is right skewed over 65 years, i.e. the ages near to 65 years old are frequent but extreme ages are few. The main difficulty is to find a distribution that fits the data in all their domain, especially at extreme value data, without underestimating or overestimating the risk. The extreme value distributions provide alternative shapes for right skewed distribution. In this paper we use different right skewed distribution for lifetime duration variable associated with individuals that are 65 years olds: Weibull, Lognormal and Champernowne distributions.

Since we were interested in the oldest population, our main concern is to fit the tail of the distribution of the lifetime duration variable, where the number of observed data are scarce. Given that the number of living individuals decreases when people get older, we can say that we are speaking about “rare events”, i.e. although we select or simulate a big sample, the number of observed data at the right extreme (oldest data) is small. Then, we propose to use an alternative estimation method of parametric distribution based on the class of minimum distance estimators, which has better robustness properties than maximum likelihood estimators (see, Scott, 2001). Specifically, we obtain the parameters of the distribution minimising an estimator of the distance between true cdf and estimated cdf.

Sample size is a key factor in determining if we use a nonparametric method versus a parametric distribution fit. A simple nonparametric approach is the empirical distribution (Emp), although this is not very useful because the estimation is only defined until the maximum observed age and does not allow us to extrapolate the distribution function beyond that. This fact could cause an underestimation of the risk, given that empirical distribution supposes that the probability of an individual surviving the maximum observed age is zero. This is unlikely if we consider that, although we could have a large sample size, the number of observed “rare events” still remain very small.

If VaR_α is calculated empirically an age in years is obtained. However, economic policies, pension and dependency regimes need to be planned considering all possible expenses; therefore, it is better to calculate the risk on a monthly basis or even smaller units. However, normally the available information is in round numbers. Therefore, we need to interpolate the cdf considering that the age is a continuous variable.

Another alternative nonparametric approach is the classical kernel estimator (CKE) that smooths the shape of the empirical distribution and “extrapolates” its behaviour when dealing with extremes. Again, since the number of sample observations in the right tail of the distribution is scarce, the CKE cannot smooth the shape of the empirical distribution and, therefore, it does not efficiently extrapolate the shape of the distribution above the maximum observed value in the sample. For this reason, we also propose a two-step estimation procedure. First, we fit a flexible parametric distribution and transform original data with the parametric estimated cdf. Second, we use a double transformed kernel estimator (DTKE) method, thus ensuring that the final result guarantees that the shape of the right tail is extrapolated more efficiently (see, Alemany et al., 2013). We consider DTKE as a semiparametric method. Although, using DTKE we incorporate some bias in the estimation, Alemany et al. (2013) proved that our proposed DTKE is a consistent estimator and its bias depends on the distance between parametric cdf used in the transformation of original data and the true cdf.

Some other approaches to forecasting mortality consider that it will follow historical trends. The fact that people live longer has been observed in recent years, so there are not many data bases that reflect this trend.

To analyze the trend of the longevity risk, we estimated the truncated cumulative distribution function, which allows us to obtain the risk conditional on the individual reaching a given age.

In this paper we present a systematic procedure to evaluate the longevity risk according to the age. In section 2 we describe the different methodologies. In section 3 we show the data and the results. Finally, we conclude in section 4.

2 Methodology

Let X be a random variable that represents lifetime duration and $F(x)$ is the corresponding cdf. We are interested in population that lives for more than 65 years, hence the aim is to estimate the truncated cdf in the domain $[a, \infty)$, where $a \geq 65$. The left-truncated cdf of X is defined in equation (1) (see, Cramér, 1946).

$$F(x|X \geq a) = \frac{F(x) - F(a)}{1 - F(a)} = G(x). \tag{1}$$

To estimate the risk of longevity we use a known measure of risk, the value-at-risk (VaR_α). The VaR_α is equal to the α quantile of the distribution:

$$VaR_\alpha(X) = G^{-1}(\alpha) = inf\{x : G(x) \geq \alpha\}, \qquad \alpha \in (0, 1), \tag{2}$$

where $(1 - \alpha)\%$ indicates the expected proportion of people who will live longer than the calculated VaR_α.

One way to estimate the VaR_α is using the truncated cdf adjustment. There are different ways of adjusting $G(x)$: to fit a parametric model, to use a nonparametric approach that does not impose any shape of the distribution to the data or to use a semiparametric approach. In the next section we give a thorough explanation of these methods.

2.1 Parametric Distributions

Given the right skewed shape of the longevity distribution, to estimate the risk we propose using an extreme value distribution (EVD). The most common EVDs with middle tail are: Lognormal and Weibull. An alternative is the Champernowne distribution. This was introduced by D.G. Champernowne in 1936. The Champernowne distribution is a heavy-tailed distribution that converges to a Pareto distribution in the tail; details can be found in Buch-larsen et al. (2005). In Table 1 we show the probability density function (pdf) and the cdf of proposed parametric distributions.

To estimate parameters we can use the maximum-likelihood estimator (MLE), that consists of maximising the probability of observing the data that we have, i.e., maximizes the likelihood function. The practical problems of the MLE approach are its lack of robustness to outliers

	$f_\theta(x)$	$F_\theta(x)$	Parameters specification in θ
Weibull	$1 - e^{-\left(\frac{x}{\beta}\right)^\alpha}$	$\frac{\alpha}{\beta}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x}{b}\right)^\alpha}$	$\alpha, \beta > 0$
Lognormal	$\frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{log(x)-\mu}{\sigma}\right)^2}$	$\Phi\left(\frac{\log(x)-\mu}{\sigma}\right)$	$\mu \in R \quad \sigma > 0$
Champernowne	$\frac{\alpha(x+c)^{\alpha-1}((M+c)^\alpha - c^\alpha)}{((x+c)^\alpha + (M+c)^\alpha - 2c^\alpha)^2}$	$\frac{(x+c)^\alpha - c^\alpha}{(x+c)^\alpha + (M+c)^\alpha - 2c^\alpha}$	$\alpha, M, c > 0$

θ is the vector of parameters.

Table 1: Parametric distributions.

and model misspecification (see, Scott, 2001). Both circumstances could occur in our analysis of the longevity.

Given that we are interested in estimating the cdf, an alternative to MLE consists of estimating the parameters minimising the distance between true cdf and estimated cdf. These ensure greater robustness than MLE to outliers and model misspecification.

A criterion that is frequently used in the nonparametric methods involves minimising the mean integrated square error (MISE):

$$\text{MISE}\left[F_{\hat{\theta}}\right] = E\left[\int \left[F_{\hat{\theta}}(t) - F_\theta(t)\right]^2 \, dt\right], \tag{3}$$

where θ is a vector of parameters, F_θ is the true cdf and $F_{\hat{\theta}}$ is the estimated cdf. The difficulty associated with calculating the MISE is that it depends on the true parameters θ.

Altman and Leger (1995) proposed to estimate MISE from its discrete approximation and replacing the true cdf by the empirical cdf (see also, Bowman et al., 1998). Let $X_1, \ldots, X_n$ be a sample of observations from the random variable X, that represents lifetime variable and has cdf $F_\theta(x)$, the empirical cdf is equal to:

$$F_n(x) = \frac{1}{n}\sum_{i=1}^{n} I(X_i \leq x), \tag{4}$$

where $I(\cdot)$ is the indicator function, it takes the value 1 if the condition between parentheses is true and zero on the contrary, then, a discrete approximation of MISE is:

$$\widehat{MISE}[F_{\hat{\theta}}] = n^{-1}\sum_{i=1}^{n}[F_{\hat{\theta}}(X_i) - F_n(X_i)]^2. \tag{5}$$

In Figure 1 we show the contour plot of $\widehat{MISE}$ associated with the estimation of the parameters of a Weibull distribution defined in[1] Table 1 (shape parameter is α and scale parameter is β). We can observe that a global minimum (darker part) exists. Similar contour plots are obtained for Lognormal and Champernowne distributions, where shape parameters are σ and α and scale parameters are μ and M, respectively.

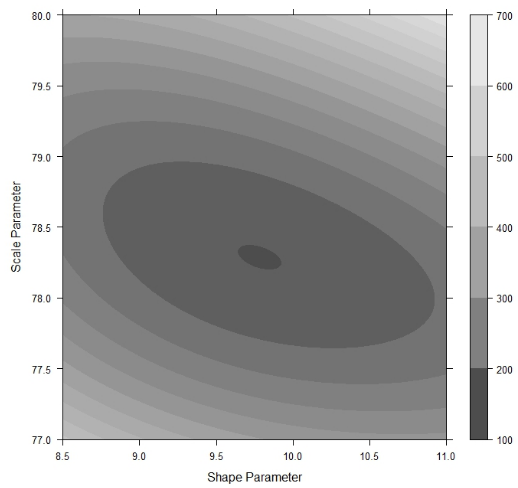


Figure 1: Contour plot of $\widehat{MISE}$ for Weibull distribution.

In order to compare MLE and $\widehat{MISE}$ criteria, in figures 2 and 3 we plot the empirical cdf with parametric cdfs estimated by MLE and minimising $\widehat{MISE}$. In both figures we show as, in general, parametric estimates based on minimising $\widehat{MISE}$ are closer to empirical cdf. Focusing on in older ages we obtain different result depending on the tail of the distribution. In our study, Weibull distribution have a lighter tail; in this case the estimation based on minimising $\widehat{MISE}$ provides a lighter tail than the MLE estimation, i.e. the estimation based on minimising $\widehat{MISE}$ increase faster than the MLE estimation. By contrast, for the Lognormal distribution, which has a heavier tail than the Weibull, the estimation based on minimising $\widehat{MISE}$ provides a slightly heavier tail than the MLE estimation. Finally, when we fit the Champernowne distribution, which is a heavy tail distribution, the estimated distribution clearly has a heavier tail when we estimate the parameters minimising $\widehat{MISE}$. In both cases, for Lognormal and

[1] For the graphic examples we use the data described in section 3.

Champernowne distributions, the estimation based on minimising $\widehat{MISE}$ increases slower than the MLE estimation.

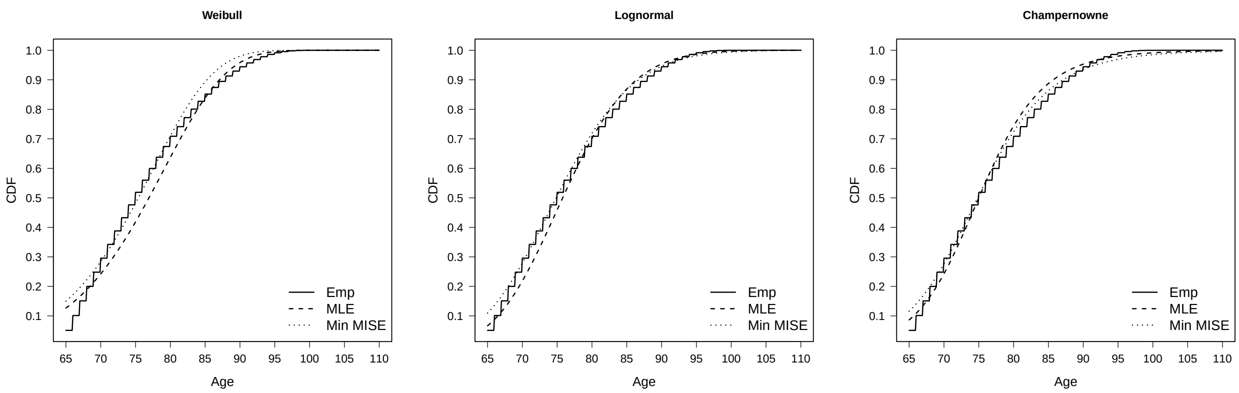


Figure 2: Lifetime variable distribution for male. Empirical cdf (solid line), MLE estimation (dashed line) and estimation based on minimizing $\widehat{MISE}$ (dotted line).

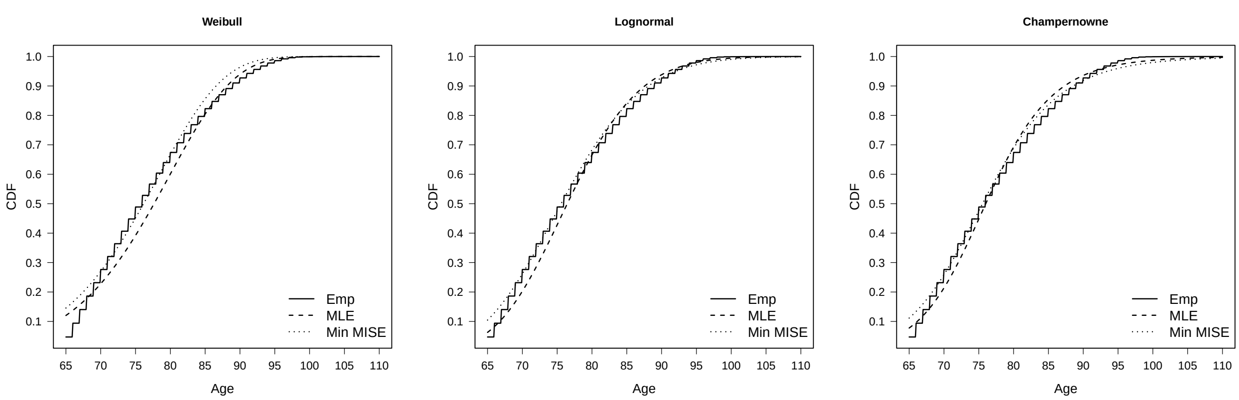


Figure 3: Lifetime variable distribution for female. Empirical cdf (solid line), MLE estimation (dashed line) and estimation based on minimizing $\widehat{MISE}$ (dotted line).

2.2 Nonparametric and semiparametric estimation

Nonparametric methods are widely used to estimate the pdf and the cdf of a random variable. The main motivation is to let the sample information itself draws the shape of the distribution; in our case, nonparametric estimations provide more flexible forms to the cdf than those given by the parametric estimation.

Nonparametric estimators of the cdf do not impose any shape to the distribution of the data. They provide an estimation for the value of the function at each point x in the domain of the random variable. However, when data is scarce nonparametric methods are not efficient and semiparametric methods may be a better alternative.

A natural nonparametric method to estimate cdf is the empirical distribution defined in (4). We can estimate the VaR replacing in (2) the theoretical truncated cdf $G(x)$ by its empirical estimation $G_n(x) = \frac{F_n(x)-F_n(a)}{1-F_n(a)} =$, where $a \geq 65$ is a given age.

The empirical distribution is very simple but it is not efficient (see, Azzalini, 1981) and cannot extrapolate beyond the maximum observed data point. This is especially troublesome when the data is scarce, as occurs when we have rare events and one may suspect that the probability of reaching older ages than the maximum observed age in the data sample is not zero. Furthermore, when empirical distribution is used to quantify the risk, the results obtained are round numbers, this occur because empirical distribution only is defined at observed age and can not be directly extrapolated. Insurance and financial companies are increasingly interested in quantifying their risks more accurately. For this reason it is important that the method allows them to draw all risk values in the set of positive real numbers, then the empirical distribution is not advisable.

An alternative to empirical distribution is the classical kernel estimation (CKE) of $F(x)$ that is:

$$\hat{F}(x) = \frac{1}{n}\sum_{i=1}^{n} K\left(\frac{x-X_i}{b}\right), \tag{6}$$

where $K(t) = \int_{-1}^{t} k(s)ds$ is the cdf associated with the kernel function $k(\cdot)$, that is usually a symmetric pdf. Some examples of very common kernel functions are the Epanechnikov and the Gaussian kernels (see, Silverman, 1986). In this paper we use the Epanechnikov kernel, $K(x) = 3/4(1-x^2)$, if $|x| \leq 1$, although kernel selection almost does not affect the estimation results. The parameter b in (6) is the smoothing parameter, also called bandwidth; it is a positive constant that controls the smoothness of the $\hat{F}$. Larger values of b return a smoother estimation. For estimating the VaR from (2) we need a numeric algorithm, for example the Newton-Raphson, that allows us to solve the equation $\hat{G}(VaR_\alpha(X)) = \alpha$, where $\hat{G}(x) = \hat{F}(x|X \geq a) = \frac{\hat{F}(x)-\hat{F}(a)}{1-\hat{F}(a)}$, being $a \geq 65$ a given age. Given that we estimate the truncated cdf for individuals over the age of 65.

The value of the smoothing parameter b considerably affects the results of the estimated cdf, especially when the goal is the estimation at a given point x for calculating the VaR. Therefore, estimating b is fundamental to obtain an accurate estimation of the VaR. In the literature, there are various proposals for calculating b based on minimising a estimated distance between F and $\hat{F}$ (see, for example, Altman and Leger, 1995; Bowman et al., 1998). The difficulty with these methods is that we can obtain different values of b with the different methods and, furthermore, when we have an EVD, these methods can degenerate to $b = 0$. To calculate smoothing parameter we use the proposal of Alemany et al. (2013) that is based on the rule-of-thumb bandwidth proposed by Silverman (1986) and takes into account the existence of extreme values:

$$\hat{b} = \hat{\sigma}^{\frac{5}{3}} \left(\frac{8}{3}\right)^{\frac{1}{3}} n^{-\frac{1}{3}}, \tag{7}$$

where $\hat{\sigma}$ is the estimated standard deviation of the random variable X.

The classical kernel estimation of a cdf as defined in equation (6) is not much different to the well-known empirical distribution in equation (4). The main difference between equations (4) and (6) is that the empirical cdf only uses data below x, giving equal weight to all observations that influence the estimation of $F(x)$, while the CKE uses all the data above and below x, giving more weight to observations that are below and, in turn, are closer to x.

The CKE smooths the stepped shape of the empirical distribution; however, when data is scarce the CKE does not allow us to accurately estimate the VaR. In Figure 4 we compare the empirical distribution with the CKE of $F(x)$, for the lifetime variable distribution for male and female.

With the aim of improving the efficiency of CKE, Alemany et al. (2013) proposed the double transformed kernel estimator (DTKE). We can summarize the procedure in three steps:

- **Step 1:** Minimizing LNO, fitting a parametric distribution function, $F_{\hat{\theta}}$ and obtain the transformed data $U_1, \ldots, U_n$ that is close to a $Uniform(0,1)$.

- **Step 2:** Transforming the uniform data using the inverse of the cdf of a $Beta\,(3,3)$, $M\,(x) = \frac{3}{16}x^5 - \frac{5}{8}x^3 + \frac{15}{16}x + \frac{1}{2}$.

- **Step 3:** Obtaining the CKE using the double transformed sample, the result is the called DTKE:

$$\widehat{F}(x) = \frac{1}{n}\sum_{i=1}^{n} K\left(\frac{M^{-1}\left(F_{\hat{\theta}}\,(x)\right) - M^{-1}\left(F_{\hat{\theta}}\,(X_i)\right)}{b}\right). \tag{8}$$

.

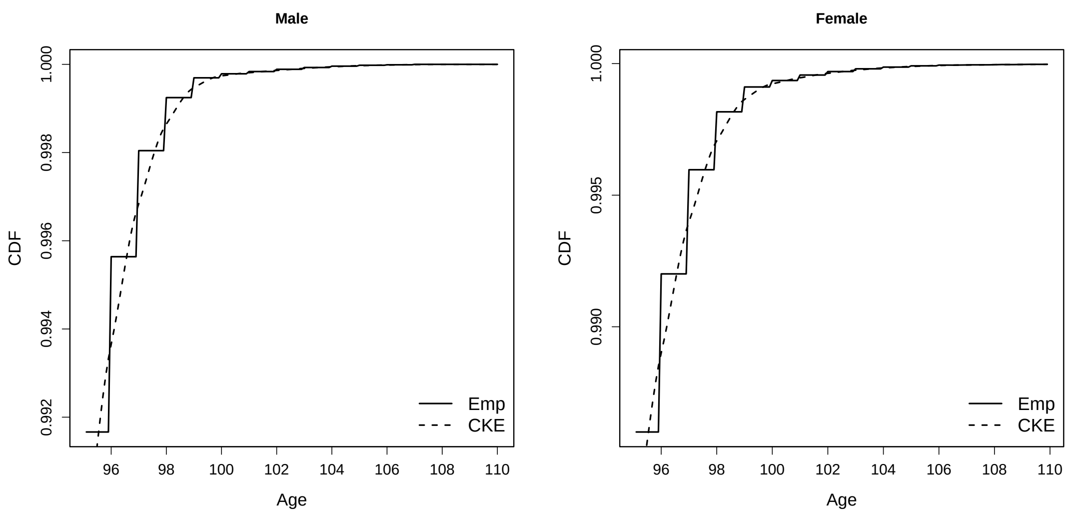


Figure 4: Lifetime variable distribution. Empirical cdf (solid line) and CKE (dashed line).

Alemany et al. (2013) propose to transform data in a $Beta$ distribution because, using CKE, the shape of the $Beta$ is better estimated than the shape of the $Uniform$. Then, the DTKE is based on the fact that the cdf of a $Beta(3,3)$ can be estimated optimally using classical kernel estimation (see, Terrell, 1990). Given that double transformed data have a distribution that is close to the $Beta(3,3)$ distribution, then an accurate optimal bandwidth for estimating cdf at VaR, $\widehat{F}^{-1}(\alpha) = \widehat{VaR}_\alpha(X) = x$:

$$\widehat{b}_x = \left(\frac{m\left(M^{-1}\left(F_{\hat{\theta}}\left(x\right)\right)\right)\left(1 - \int_{-1}^{1} K^2\left(t\right)dt\right)}{4\left[\frac{1}{2}m'\left(M^{-1}\left(F_{\hat{\theta}}\left(x\right)\right)\right)\int_{-1}^{1} t^2 k\left(t\right)dt\right]^2} \right)^{\frac{1}{3}} n^{-\frac{1}{3}}, \tag{9}$$

where $m = M'$ is the pdf of the $Beta\,(3,3)$ distribution.

Alemany et al. (2013) suggested using a pseudo-maximum-likelihood estimation of Champernowne distribution in **Step 1**. Alternatively, we decided to select one of the distributions that we described in Table 1 and to use the one that minimises the $\widehat{MISE}$. This generalization does not affect asymptotic properties of DTKE and improves finite sample properties.

In figures 5 and 6 we have plotted parametric fitted distributions together with, the empirical distribution and the DTKE obtained using the different prior parametric distributions. Both figures evidence that using sample information the DTKE improves the parametric fit by reducing its bias. Furthermore, the DTKE improves the efficiency of the estimators that are only based on sample information, i.e. empirical distribution and CKE.

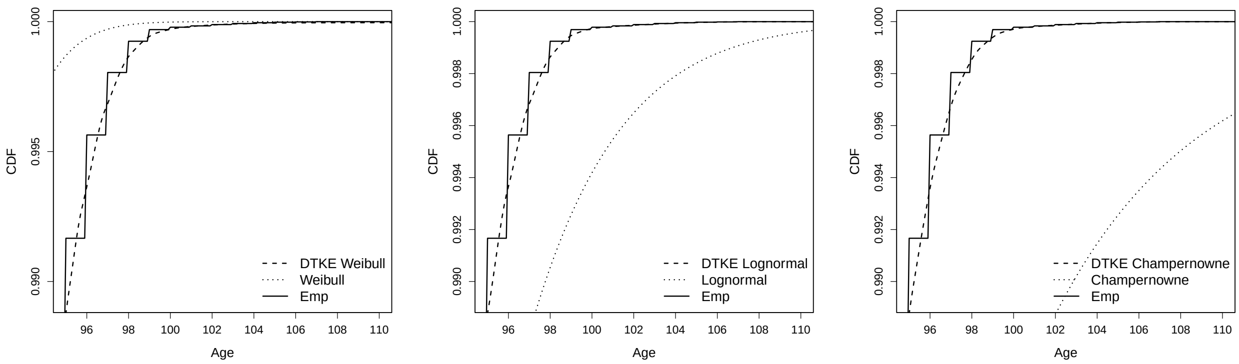


Figure 5: Lifetime variable distribution for male. DTKE with prior Lognormal cdf (solid line) DTKE with prior Champernowne cdf (dashed line) and DTKE with prior Weibull cdf (dotted line).

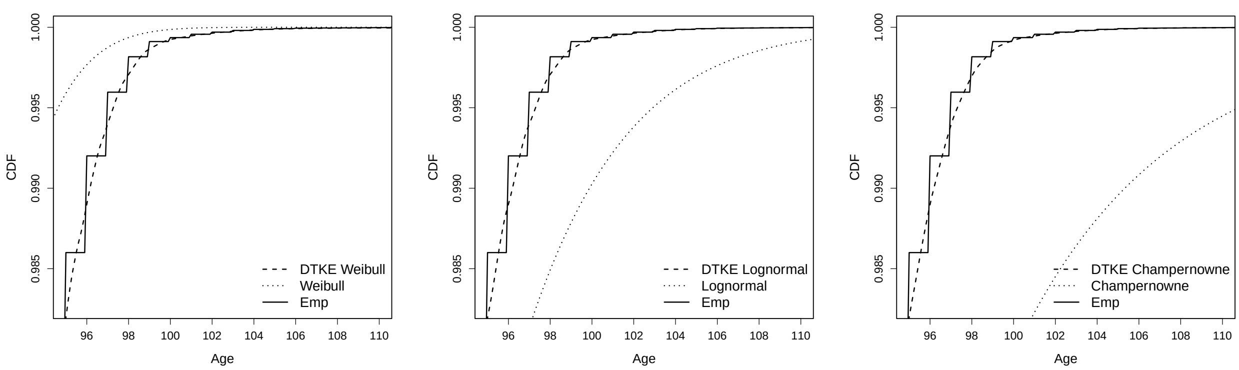


Figure 6: Lifetime variable distribution for male. Empirical cdf (solid line) DTKE (dashed line) and parametric fit (dotted line).

We compare the different DTKE obtained using the different prior parametric distributions. Figures 7 and 8 show the three DTKE that were obtained, respectively, for male and female. To analyse the main differences between the three estimated cdfs, we plot age above 95 and the plots have been split into two intervals [95; 99) and [99;110). We can see that when we use a heavier tailed prior parametric distribution, the cdf estimated increase more slowly, i.e. we will estimate greater risk. Note that, basically, the prior distribution has a greater influence in the most extreme ages.

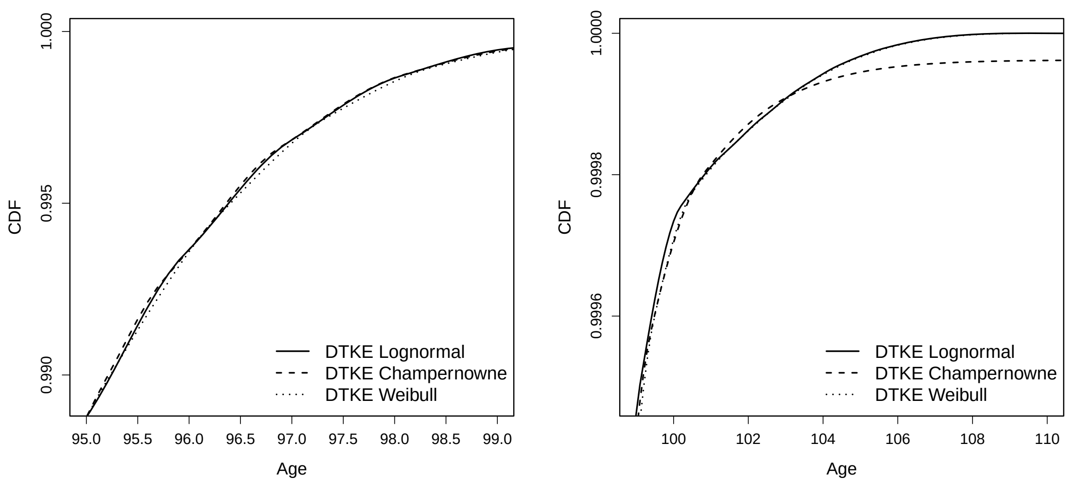


Figure 7: Lifetime variable distribution for male. DTKE with prior Lognormal cdf (solid line) DTKE with prior Champernowne cdf (dashed line) and DTKE with prior Weibull cdf (dotted line).

3 Data Analysis

Methodology described in section 2 has been used to estimate the longevity risk of the Mexican population covered by insurance. We use a simulated database from the mortality tables of those insured. The sources of information were the Mexican Association of Insurance Institutions (AMIS) and Mexican Insurers Association (AMA). Since 2000, these two institutions construct a mortality table every five years. They used policies from the most important insurance companies in Mexico. Methodology calculation is in Rendón (2012). We used the mortality table published in 2010.

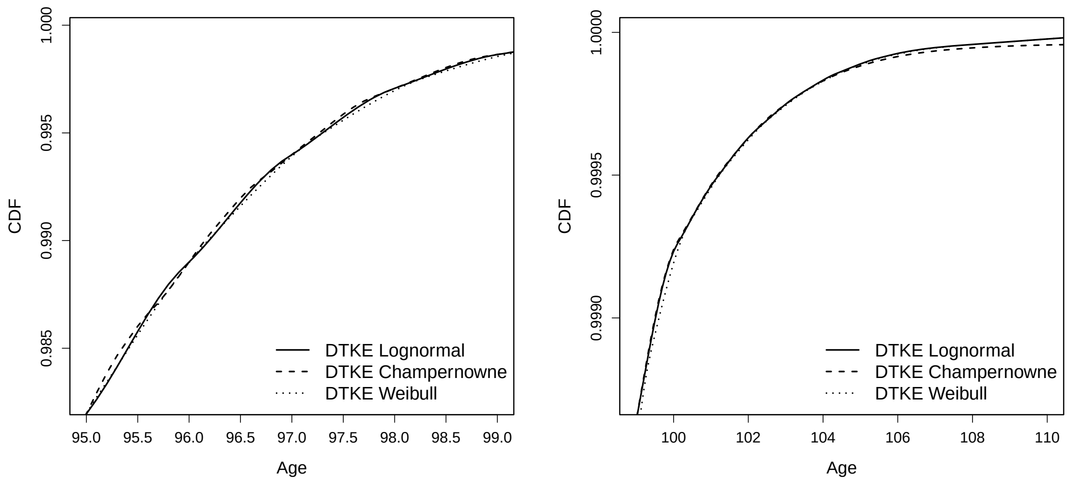


Figure 8: Lifetime variable distribution for female. DTKE with prior Lognormal cdf (solid line) DTKE with prior Champernowne cdf (dashed line) and DTKE with prior Weibull cdf (dotted line).

Given that our main interest is to evaluate the longevity risk we supposed that the survivors at 100 will die randomly until the entire population disappears. Uniform distribution was used to decide whether a subject died or survived. We analyse people over 65. The oldest ages were 107 for males and 112 for females.

For each gender, we have simulated a data set with an initial population including $N = 5,000$ individuals aged 65. In order to obtain the number of deaths, mortality rates were applied to the survivors at each age x. The number of survivors at age $x+1$ was calculated as the difference between the survivors to age x and number of deaths at age x. We repeated this process until the oldest age recorded. The sample size is equal to the sum of all the survivors at every age.

The figures 9 and 10 show the histogram of lifetime simulated data for male and female, respectively. To observe the density in extreme ages, the histogram was been split into two intervals $[65; 98]$ and > 98. As is expected, if data were plotted we would obtain a right skewed distribution, where the probability of a extreme age is small but it is not zero.

As an alternative to the MLE estimates, in section 2 we explained the method based on minimizing $\widehat{MISE}$ expressed in (5). The Table 2 shows the estimated parameters by MLE

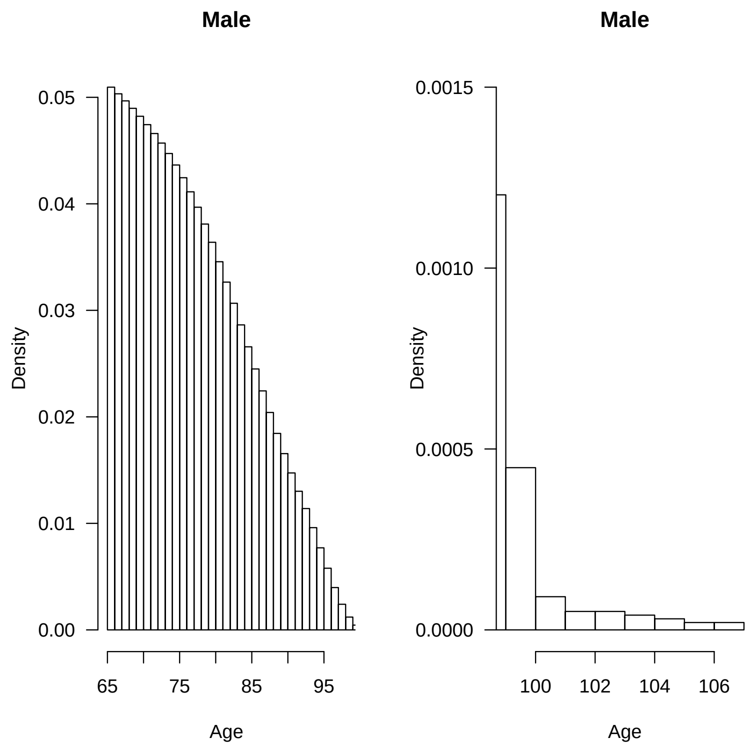


Figure 9: Histogram of lifetime simulated data for male.

and minimizing $\widehat{MISE}$ for the Weibull, Lognormal and Champernowne distributions. The two first distributions have a lighter tail than the Champernowne distribution. We have observed that for Lognormal distribution and Weibull distribution the estimated parameters are similar for both estimation method. Indeed, the shape parameters of Champernowne distributions estimated by minimum $\widehat{MISE}$ are lower than those estimated by MLE; consequently, the distributions have a heavy right tail. In the last column of Tabla 2 are the values of $\widehat{MISE}$ for each parametric distribution for male and female, we conclude that the distribution that best fits the cdf of the lifetime variable is the Lognormal. Followed closely by the Champernowne. We use these both distribution

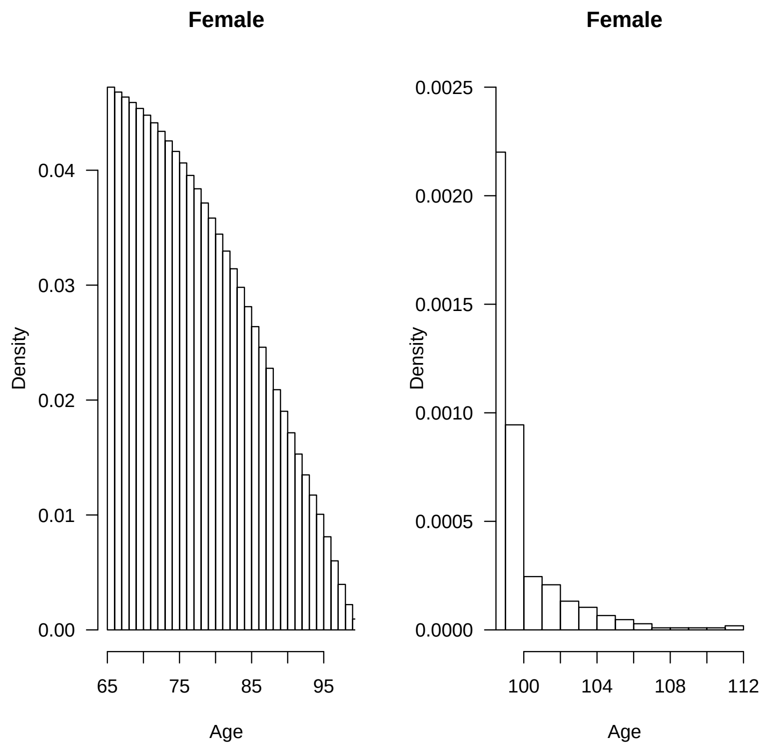


Figure 10: Histogram of lifetime simulated data for female.

		MLE		**Minimizing $\widehat{MISE}$**		
		Shape	**Scale**	**Shape**	**Scale**	$\widehat{MISE}$
Male	Weibull	9.70	79.89	9.78	78.29	149.88
	Lognormal	0.10	4.33	0.11	4.32	37.69
	Champernowne	16.48	75.00	14.44	74.83	48.27
Female	Weibull	9.49	80.72	9.36	79.19	151.28
	Lognormal	0.10	4.33	0.12	4.32	38.39
	Champernowne	15.83	76.00	13.82	75.53	51.84

Table 2: Parameters estimates by MLE and based on minimizing $\widehat{MISE}$.

The figures 11 and 12 plot the curves associated with the estimated VaR for individuals 65 and 85 years old, the results are obtained using parametric, semiparametric and nonparametric methods, respectively, for male and female. Given the results in Table 2, with the empirical distribution, we show longevity risk estimated with Lognormal and Champernowne distributions and using the CKE and the DTKE with the Lognormal and the Champernowne cdf as prior transformation. Clearly parametric models provide a biased estimation of the VaR for all confidence level, both models overestimate the longevity risk. When we use nonparametric and semiparametric methods the curves associated with estimated VaR are near and smooth the empirical VaR, although there exist some differences between the three plotted curves. In general, the greatest risk is estimated with DTKE with Champernowne prior transformation.

In Table 3 we show the longevity risk estimated in months using the DTKE with the Lognormal and the Champernowne cdf as prior transformation. We have estimated the VaR with 99%, 99.5% and 99.9% confidence level for three truncated distributions: at 65 years old, at 75 years old and at 85 years old.

		Male			**Female**		
α		**65**	**75**	**85**	**65**	**75**	**85**
99%	**DTKE Lognormal**	1143	1156	1174	1154	1166	1183
	DTKE Champernowne	1143	1157	1175	1154	1166	1184
99.5%	**DTKE Lognormal**	1157	1168	1183	1168	1178	1195
	DTKE Champernowne	1157	1168	1184	1168	1178	1196
99.9%	**DTKE Lognormal**	1180	1189	1218	1194	1212	1244
	DTKE Champernowne	1181	1190	1218	1195	1213	1245

Table 3: Value-at-risk

4 Conclusions

This paper has shown how the variable lifetime duration could be modelled following different approaches: parametric and nonparametric. One contribution of the article was to apply the minimum LNO method that enabled us to compare several cumulative distributions functions regardless of their method of estimation. Additionally, the LNO was used in the parametric framework as a method of estimation. Both cases are easily programmable. Particularly, optimal parameters were found very rapidly, since LNO converge quickly to a global minimum when maximun likelihood parameters are used as a seed.

The advantage of using LNO as estimation method is to add flexibility to the fitted cdf. In other words, the shape parameter changes in order to achieve the observed distribution. This fact was specially important for our estimation, since the distribution of our data is very specific. The LNO criterion provide a better fit than MLE. We found that, for male and female population the best parametric fit was the Lognormal distribution.

Even though the Lognormal distribution is the best fit for males, this estimation does not recreate the real behavior of the observed data in the tails. That is easy to see when value-at-risk was calculated, when the confidence level increase, the VaR_α goes to ages that are unlikely to be attained. In this case, VaR_α does not reflect the natural age limit. Specifically, the parametric models does not consider the fact that the probability of survival age x moves according to the age reached.

As we have observed, parametric distributions do not provide a good estimation of the lifetime duration variable; when truncated age and/or confidence levels vary, the VaR_α is underestimated or overestimated. Nonparametric methods are a good alternative when accuracy is necessary.

Empirical distribution is the simplest nonparametric estimate of the cdf. Although it is easy to calculate, it has some drawbacks: being imposible to extrapolate, it is unlikely to find the exact quantile for any α and it is not possible to consider decimals, because all the data are integers. This last point is particularly important because in respect of very old ages, survival in month or even in days is extremely relevant.

In this case, it is better to consider the CKE or DTKE as methods of estimation. These estimator cdf smooth the empirical distribution. One advantage of then is that the risk can be evaluated in all the domain of the variable. As a result, no matter the confidence level that has been established, an exact VaR_α is obtained.

Finally, estimating the cdf allows us to calculate the survival functions and consequently the mortality rates. VaR_α is directly calculated from the estimated cdf. Nonparametric methods are more consistent to this data than parametric methods.

Even though the Lognormal distribution is the best fit for males, this estimation does not recreate the real behaviour of the observed data in the tails. When the confidence level increases, the VaR_α goes to ages that are unlikely to be attained; then, VaR_α does not reflect the natural age limit. The double transformed kernel estimation of the longevity risk that we propose in this paper is an excellent approach; on one hand, it improves the efficiency of alternative nonparametric estimation and, on other hand, it addresses the possible large bias in finite sample and the possible inconsistency of parametric estimation.

Acknowledgements

We thank the Spanish Ministry of Science / ECO2016- 76203-C2-2-P. We also thank members and affiliates of Riskcenter at the University of Barcelona.

References

Alemany, R., Bolancé, C., Guillén, M., 2013. A nonparametric approach to calculating value-at-risk. Insurance: Mathematics and Economics 52, 255–262. URL: http://linkinghub.elsevier.com/retrieve/pii/S0167668713000048, doi:10.1016/j.insmatheco.2012.12.008.

Altman, N., Leger, C., 1995. Bandwidth selection for kernel distribution function estimation. Journal of Statistical Planning and Inference 46, 195–214.

Azzalini, A., 1981. A note on the estimation of a distribution function and quantiles by a kernel method. Biometrika 68, 326–328. URL: http://biomet.oxfordjournals.org/content/68/1/326.short.

Bowman, A., Hall, P., Prvan, T., 1998. Bandwidth selection for the smoothing of distribution functions. Biometrika 85, 799–808.

Buch-larsen, T., Nielsen, J.P., Guillén, M., Bolancé, C., 2005. Kernel density estimation for heavy-tailed distributions using the champernowne transformation. Statistics 39, 503–516. URL: http://www.tandfonline.com/doi/abs/10.1080/02331880500439782, doi:10.1080/02331880500439782.

Cheung, S.L.K., Robine, Jean-Marie, Jow-Ching, E., Caselli, G., 2005. Three dimensions of the survival curve: horizontalization, verticalization, and longevity extension. Demography 42, 243–58. URL: http://www.ncbi.nlm.nih.gov/pubmed/15986985.

Cramér, H., 1946. Mathematical Methods of Statistics. Princeton University Press.

Fries, J.F., 1980. Aging, natural death, and the compression of morbidity. New England Journal of Medicine 303, 130–135. URL: http://www.nejm.org/doi/full/10.1056/NEJM198007173030304, doi:10.4054/DemRes.2000.3.6.

Kannisto, V., 2000. Measuring the compression of mortality. Demographic Research 3. URL: http://www.demographic-research.org/volumes/vol3/6/, doi:10.4054/DemRes.2000.3.6.

Ornelas, A., Guillén, M., Alcañiz, M., 2013. Implications of unisex assumptions in the analysis of longevity for insurance portfolios, in: Fernández-Izquierdo, M.A., Muñoz Torres, M.J., León, R. (Eds.), Modeling and Simulation in Engineering, Economics, and Management. Springer Berlin Heidelberg. Lecture Notes in Business Information Processing, pp. 99–107. doi:10.1007/978-3-642-38279-6_11.

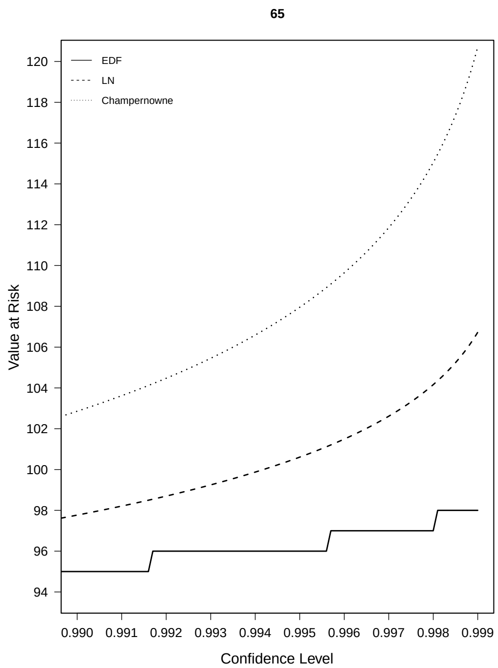
Rendón, J., 2012. The construction of multiple decrement models from associated single decrement experiences.

Scott, D.W., 2001. Parametric Statistical Modeling by Minimum Integrated Square Error. Technometrics 43, 274–285. URL: http://www.tandfonline.com/doi/abs/10.1198/004017001316975880, doi:10.1198/004017001316975880.

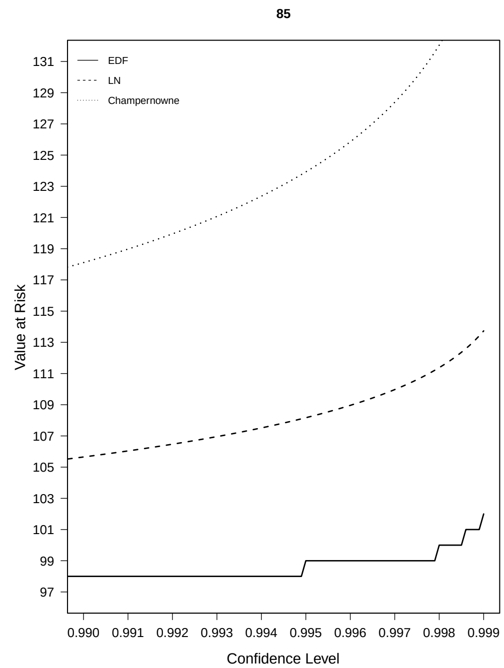
Silverman, B., 1986. Density Estimation for Statistics and Data Analysis. Chapman & Hall/CRC Monographs on Statistics & Applied Probability, Taylor & Francis.

Terrell, G.R., 1990. The Maximal Smoothing Principle in Density Estimation. Journal of the American Statistical Association 85, 470–477.

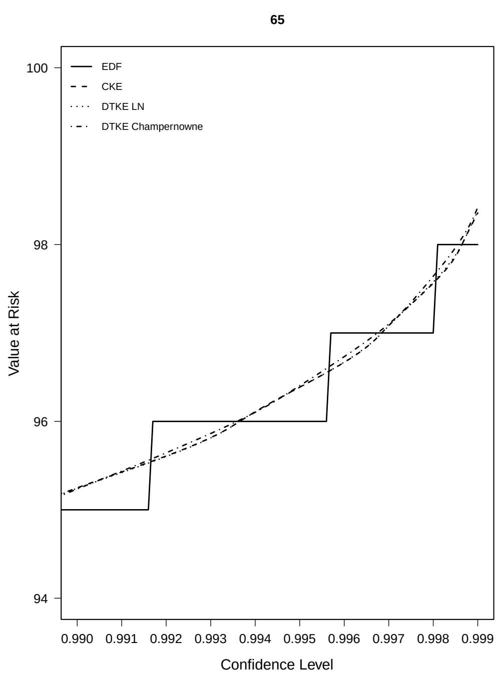
Yue, J.C., 2011. Mortality Compression and Longevity Risk .



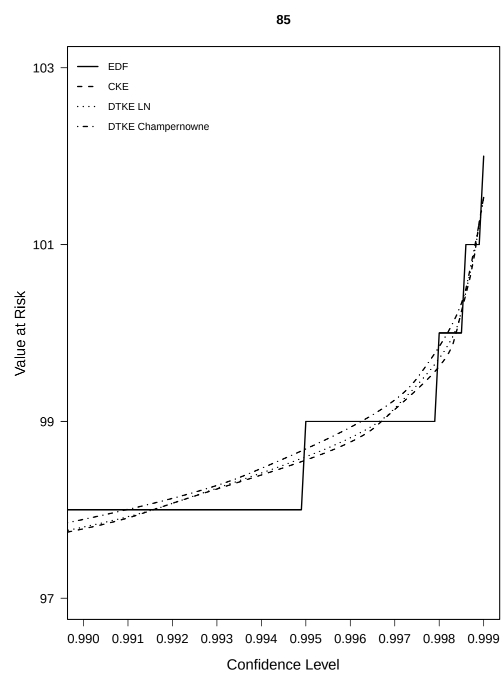
(a) Age 65 Parametric



(b) Age 85 Parametric

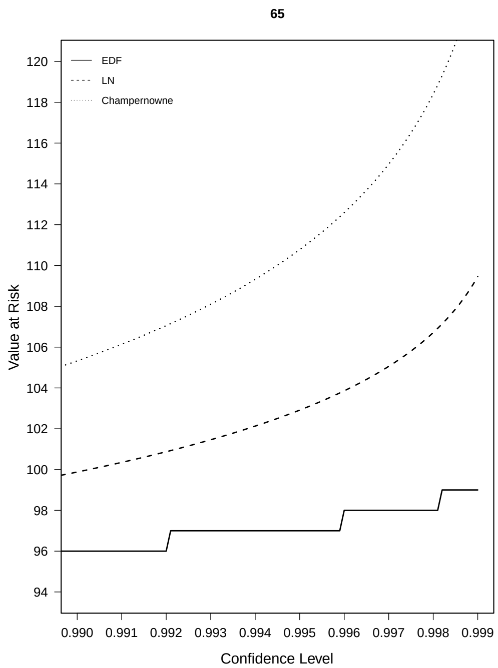


(c) Age 65 Nonparametric

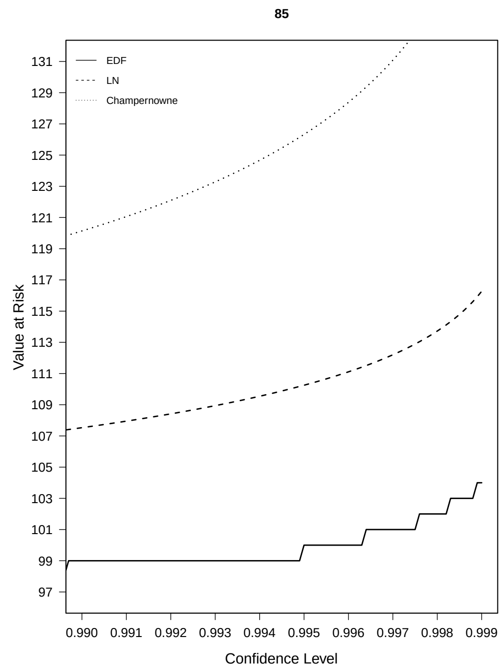


(d) Age 85 Nonparametric

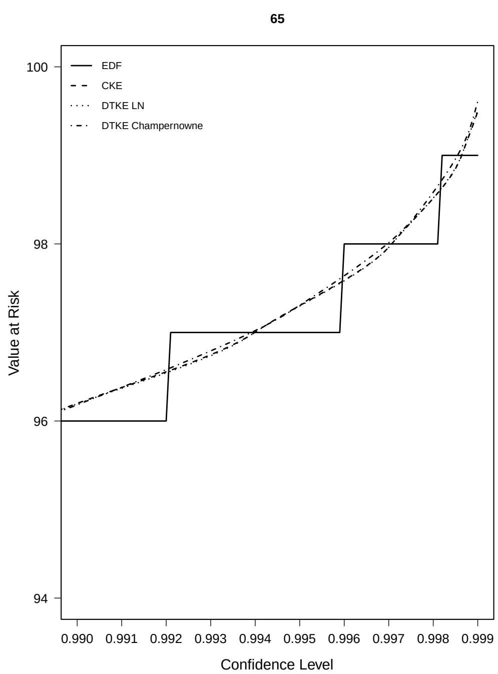
Figure 11: Comparing different estimated VaR_α for males.



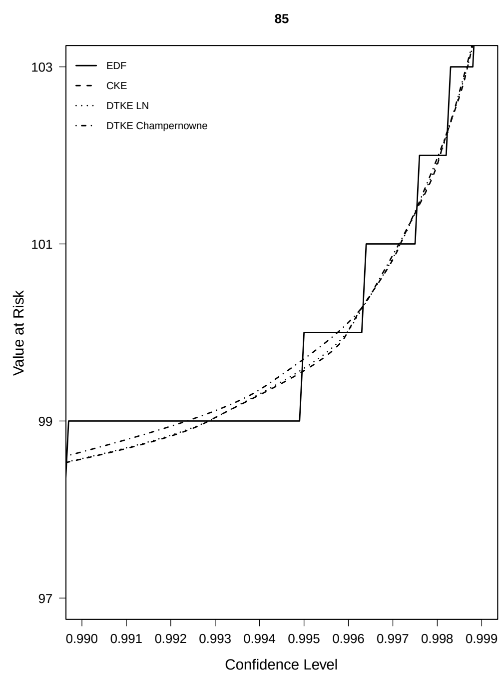
(a) Age 65 Parametric



(b) Age 85 Parametric



(c) Age 65 Nonparametric



(d) Age 85 Nonparametric

Figure 12: Comparing different estimated VaR_α for females.

2006

CREAP2006-01
Matas, A. (GEAP)**; Raymond, J.Ll.** (GEAP)
"Economic development and changes in car ownership patterns"
(Juny 2006)

CREAP2006-02
Trillas, F. (IEB)**; Montolio, D.** (IEB)**; Duch, N.** (IEB)
"Productive efficiency and regulatory reform: The case of Vehicle Inspection Services"
(Setembre 2006)

CREAP2006-03
Bel, G. (PPRE-IREA)**; Fageda, X.** (PPRE-IREA)
"Factors explaining local privatization: A meta-regression analysis"
(Octubre 2006)

CREAP2006-04
Fernàndez-Villadangos, L. (PPRE-IREA)
"Are two-part tariffs efficient when consumers plan ahead?: An empirical study"
(Octubre 2006)

CREAP2006-05
Artís, M. (AQR-IREA)**; Ramos, R.** (AQR-IREA)**; Suriñach, J.** (AQR-IREA)
"Job losses, outsourcing and relocation: Empirical evidence using microdata"
(Octubre 2006)

CREAP2006-06
Alcañiz, M. (RISC-IREA)**; Costa, A.; Guillén, M.** (RISC-IREA)**; Luna, C.; Rovira, C.**
"Calculation of the variance in surveys of the economic climate"
(Novembre 2006)

CREAP2006-07
Albalate, D. (PPRE-IREA)
"Lowering blood alcohol content levels to save lives: The European Experience"
(Desembre 2006)

CREAP2006-08
Garrido, A. (IEB)**; Arqué, P.** (IEB)
"The choice of banking firm: Are the interest rate a significant criteria?"
(Desembre 2006)

CREAP2006-09
Segarra, A. (GRIT)**; Teruel-Carrizosa, M.** (GRIT)
"Productivity growth and competition in spanish manufacturing firms:
What has happened in recent years?"
(Desembre 2006)

CREAP2006-10
Andonova, V.; Díaz-Serrano, Luis. (CREB)
"Political institutions and the development of telecommunications"
(Desembre 2006)

CREAP2006-11
Raymond, J.L.(GEAP)**; Roig, J.L..** (GEAP)
"Capital humano: un análisis comparativo Catalunya-España"
(Desembre 2006)

CREAP2006-12
Rodríguez, M.(CREB)**; Stoyanova, A.** (CREB)
"Changes in the demand for private medical insurance following a shift in tax incentives"
(Desembre 2006)

CREAP2006-13
Royuela, V. (AQR-IREA)**; Lambiri, D.**; **Biagi, B.**
"Economía urbana y calidad de vida. Una revisión del estado del conocimiento en España"
(Desembre 2006)

CREAP2006-14

Camarero, M.; Carrion-i-Silvestre, J.LL. (AQR-IREA)**.**;**Tamarit**, **C.**
"New evidence of the real interest rate parity for OECD countries using panel unit root tests with breaks”
(Desembre 2006)

CREAP2006-15
Karanassou, M.; Sala, H. (GEAP)**.**;**Snower** , **D. J.**
"The macroeconomics of the labor market: Three fundamental views”
(Desembre 2006)

2007

XREAP2007-01
Castany, L (AQR-IREA)**; López-Bazo, E.** (AQR-IREA)**.**;**Moreno** , **R.** (AQR-IREA)
"Decomposing differences in total factor productivity across firm size”
(Març 2007)

XREAP2007-02
Raymond, J. Ll. (GEAP)**; Roig, J. Ll.** (GEAP)
“Una propuesta de evaluación de las externalidades de capital humano en la empresa"
(Abril 2007)

XREAP2007-03
Durán, J. M. (IEB)**; Esteller, A.** (IEB)
“An empirical analysis of wealth taxation: Equity vs. Tax compliance”
(Juny 2007)

XREAP2007-04
Matas, A. (GEAP)**; Raymond, J.Ll.** (GEAP)
“Cross-section data, disequilibrium situations and estimated coefficients: evidence from car ownership demand”
(Juny 2007)

XREAP2007-05
Jofre-Montseny, J. (IEB)**; Solé-Ollé, A.** (IEB)
“Tax differentials and agglomeration economies in intraregional firm location”
(Juny 2007)

XREAP2007-06
Álvarez-Albelo, C. (CREB)**; Hernández-Martín, R.**
“Explaining high economic growth in small tourism countries with a dynamic general equilibrium model”
(Juliol 2007)

XREAP2007-07
Duch, N. (IEB)**; Montolio, D.** (IEB); **Mediavilla, M.**
“Evaluating the impact of public subsidies on a firm’s performance: a quasi-experimental approach”
(Juliol 2007)

XREAP2007-08
Segarra-Blasco, A. (GRIT)
“Innovation sources and productivity: a quantile regression analysis”
(Octubre 2007)

XREAP2007-09
Albalate, D. (PPRE-IREA)
“Shifting death to their Alternatives: The case of Toll Motorways”
(Octubre 2007)

XREAP2007-10
Segarra-Blasco, A. (GRIT); **Garcia-Quevedo, J.** (IEB); **Teruel-Carrizosa, M.** (GRIT)
“Barriers to innovation and public policy in catalonia”
(Novembre 2007)

XREAP2007-11
Bel, G. (PPRE-IREA); **Foote, J.**
“Comparison of recent toll road concession transactions in the United States and France”
(Novembre 2007)

XREAP2007-12
Segarra-Blasco, A. (GRIT);
“Innovation, R&D spillovers and productivity: the role of knowledge-intensive services”
(Novembre 2007)

XREAP2007-13
Bermúdez Morata, Ll. (RFA-IREA); **Guillén Estany, M.** (RFA-IREA), **Solé Auró, A**. (RFA-IREA)
"Impacto de la inmigración sobre la esperanza de vida en salud y en discapacidad de la población española"
(Novembre 2007)

XREAP2007-14
Calaeys, P. (AQR-IREA); **Ramos, R.** (AQR-IREA), **Suriñach, J**. (AQR-IREA)
"Fiscal sustainability across government tiers"
(Desembre 2007)

XREAP2007-15
Sánchez Hugalbe, A. (IEB)
"Influencia de la inmigración en la elección escolar"
(Desembre 2007)

2008

XREAP2008-01
Durán Weitkamp, C. (GRIT)**; Martín Bofarull, M.** (GRIT) ; **Pablo Martí, F.**
"Economic effects of road accessibility in the Pyrenees: User perspective"
(Gener 2008)

XREAP2008-02
Díaz-Serrano, L.; Stoyanova, A. P. (CREB)
"The Causal Relationship between Individual's Choice Behavior and Self-Reported Satisfaction: the Case of Residential Mobility in the EU"
(Març 2008)

XREAP2008-03
Matas, A. (GEAP)**; Raymond, J. L.** (GEAP)**; Roig, J. L.** (GEAP)
"Car ownership and access to jobs in Spain"
(Abril 2008)

XREAP2008-04
Bel, G. (PPRE-IREA) **; Fageda, X.** (PPRE-IREA)
"Privatization and competition in the delivery of local services: An empirical examination of the dual market hypothesis"
(Abril 2008)

XREAP2008-05
Matas, A. (GEAP); **Raymond, J. L.** (GEAP); **Roig, J. L.** (GEAP)
"**Job accessibility and employment probability**"
(Maig 2008)

XREAP2008-06
Basher, S. A.; Carrión, J. Ll. (AQR-IREA)
Deconstructing Shocks and Persistence in OECD Real Exchange Rates
(Juny 2008)

XREAP2008-07
Sanromá, E. (IEB)**; Ramos, R.** (AQR-IREA); Simón, H.
Portabilidad del capital humano y asimilación de los inmigrantes. Evidencia para España
(Juliol 2008)

XREAP2008-08
Basher, S. A.; Carrión, J. Ll. (AQR-IREA)
Price level convergence, purchasing power parity and multiple structural breaks: An application to US cities
(Juliol 2008)

XREAP2008-09
Bermúdez, Ll. (RFA-IREA)
A priori ratemaking using bivariate poisson regression models
(Juliol 2008)

XREAP2008-10
Solé-Ollé, A. (IEB), **Hortas Rico, M.** (IEB)
Does urban sprawl increase the costs of providing local public services? Evidence from Spanish municipalities
(Novembre 2008)

XREAP2008-11
Teruel-Carrizosa, M. (GRIT), **Segarra-Blasco, A.** (GRIT)
Immigration and Firm Growth: Evidence from Spanish cities
(Novembre 2008)

XREAP2008-12
Duch-Brown, N. (IEB), **García-Quevedo, J.** (IEB), **Montolio, D.** (IEB)
Assessing the assignation of public subsidies: Do the experts choose the most efficient R&D projects?
(Novembre 2008)

XREAP2008-13
Bilotkach, V., **Fageda, X.** (PPRE-IREA), **Flores-Fillol, R.**
Scheduled service versus personal transportation: the role of distance
(Desembre 2008)

XREAP2008-14
Albalate, D. (PPRE-IREA), **Gel, G.** (PPRE-IREA)
Tourism and urban transport: Holding demand pressure under supply constraints
(Desembre 2008)

2009

XREAP2009-01
Calonge, S. (CREB)**; Tejada, O.**
"A theoretical and practical study on linear reforms of dual taxes"
(Febrer 2009)

XREAP2009-02
Albalate, D. (PPRE-IREA)**; Fernández-Villadangos, L.** (PPRE-IREA)
"Exploring Determinants of Urban Motorcycle Accident Severity: The Case of Barcelona"
(Març 2009)

XREAP2009-03
Borrell, J. R. (PPRE-IREA)**; Fernández-Villadangos, L.** (PPRE-IREA)
"Assessing excess profits from different entry regulations"
(Abril 2009)

XREAP2009-04
Sanromá, E. (IEB)**; Ramos, R.** (AQR-IREA), **Simon, H.**
"Los salarios de los inmigrantes en el mercado de trabajo español. ¿Importa el origen del capital humano?"
(Abril 2009)

XREAP2009-05
Jiménez, J. L.; Perdiguero, J. (PPRE-IREA)
"(No)competition in the Spanish retailing gasoline market: a variance filter approach"
(Maig 2009)

XREAP2009-06
Álvarez-Albelo,C. D. (CREB)**, Manresa, A.** (CREB)**, Pigem-Vigo, M.** (CREB)
"International trade as the sole engine of growth for an economy"
(Juny 2009)

XREAP2009-07
Callejón, M. (PPRE-IREA)**, Ortún V, M.**
"The Black Box of Business Dynamics"
(Setembre 2009)

XREAP2009-08
Lucena, A. (CREB)
"The antecedents and innovation consequences of organizational search: empirical evidence for Spain"
(Octubre 2009)

XREAP2009-09
Domènech Campmajó, L. (PPRE-IREA)
"Competition between TV Platforms"
(Octubre 2009)

XREAP2009-10
Solé-Auró, A. (RFA-IREA),**Guillén, M.** (RFA-IREA)**, Crimmins, E. M.**
"Health care utilization among immigrants and native-born populations in 11 European countries. Results from the Survey of Health, Ageing and Retirement in Europe"
(Octubre 2009)

XREAP2009-11
Segarra, A. (GRIT)**, Teruel, M.** (GRIT)
"Small firms, growth and financial constraints"
(Octubre 2009)

XREAP2009-12
Matas, A. (GEAP)**, Raymond, J.Ll.** (GEAP), **Ruiz, A.** (GEAP)
"Traffic forecasts under uncertainty and capacity constraints"
(Novembre 2009)

XREAP2009-13
Sole-Ollé, A. (IEB)
"Inter-regional redistribution through infrastructure investment: tactical or programmatic?"
(Novembre 2009)

XREAP2009-14
Del Barrio-Castro, T., **García-Quevedo, J.** (IEB)
"The determinants of university patenting: Do incentives matter?"
(Novembre 2009)

XREAP2009-15
Ramos, R. (AQR-IREA), **Suriñach, J.** (AQR-IREA)**, Artís, M.** (AQR-IREA)
"Human capital spillovers, productivity and regional convergence in Spain"
(Novembre 2009)

XREAP2009-16
Álvarez-Albelo, C. D. (CREB), **Hernández-Martín, R.**
"The commons and anti-commons problems in the tourism economy"
(Desembre 2009)

2010

XREAP2010-01
García-López, M. A. (GEAP)
"The Accessibility City. When Transport Infrastructure Matters in Urban Spatial Structure"
(Febrer 2010)

XREAP2010-02
García-Quevedo, J. (IEB), **Mas-Verdú, F.** (IEB), **Polo-Otero, J.** (IEB)
"Which firms want PhDs? The effect of the university-industry relationship on the PhD labour market"
(Març 2010)

XREAP2010-03
Pitt, D., **Guillén, M.** (RFA-IREA)
"An introduction to parametric and non-parametric models for bivariate positive insurance claim severity distributions"
(Març 2010)

XREAP2010-04
Bermúdez, Ll. (RFA-IREA), **Karlis, D.**
"Modelling dependence in a ratemaking procedure with multivariate Poisson regression models"
(Abril 2010)

XREAP2010-05
Di Paolo, A. (IEB)
"Parental education and family characteristics: educational opportunities across cohorts in Italy and Spain"
(Maig 2010)

XREAP2010-06
Simón, H. (IEB), **Ramos, R.** (AQR-IREA), **Sanromá, E.** (IEB)

"Movilidad ocupacional de los inmigrantes en una economía de bajas cualificaciones. El caso de España"
(Juny 2010)

XREAP2010-07
Di Paolo, A. (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB)
"Language knowledge and earnings in Catalonia"
(Juliol 2010)

XREAP2010-08
Bolancé, C. (RFA-IREA), **Alemany, R.** (RFA-IREA), **Guillén, M.** (RFA-IREA)
"Prediction of the economic cost of individual long-term care in the Spanish population"
(Setembre 2010)

XREAP2010-09
Di Paolo, A. (GEAP & IEB)
"Knowledge of catalan, public/private sector choice and earnings: Evidence from a double sample selection model"
(Setembre 2010)

XREAP2010-10
Coad, A., **Segarra, A.** (GRIT), **Teruel, M.** (GRIT)
"Like milk or wine: Does firm performance improve with age?"
(Setembre 2010)

XREAP2010-11
Di Paolo, A. (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB), **Calero, J.** (IEB)
"Exploring educational mobility in Europe"
(Octubre 2010)

XREAP2010-12
Borrell, A. (GiM-IREA), **Fernández-Villadangos, L.** (GiM-IREA)
"Clustering or scattering: the underlying reason for regulating distance among retail outlets"
(Desembre 2010)

XREAP2010-13
Di Paolo, A. (GEAP & IEB)
"School composition effects in Spain"
(Desembre 2010)

XREAP2010-14
Fageda, X. (GiM-IREA), **Flores-Fillol, R.**
"Technology, Business Models and Network Structure in the Airline Industry"
(Desembre 2010)

XREAP2010-15
Albalate, D. (GiM-IREA), **Bel, G.** (GiM-IREA), **Fageda, X.** (GiM-IREA)
"Is it Redistribution or Centralization? On the Determinants of Government Investment in Infrastructure"
(Desembre 2010)

XREAP2010-16
Oppedisano, V., **Turati, G.**
"What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA"
(Desembre 2010)

XREAP2010-17
Canova, L., **Vaglio, A.**
"Why do educated mothers matter? A model of parental help"
(Desembre 2010)

2011

XREAP2011-01
Fageda, X. (GiM-IREA), **Perdiguero, J.** (GiM-IREA)
"An empirical analysis of a merger between a network and low-cost airlines"
(Maig 2011)

XREAP2011-02
Moreno-Torres, I. (ACCO, CRES & GiM-IREA)
"What if there was a stronger pharmaceutical price competition in Spain? When regulation has a similar effect to collusion"
(Maig 2011)

XREAP2011-03
Miguélez, E. (AQR-IREA); **Gómez-Miguélez, I.**
"Singling out individual inventors from patent data"
(Maig 2011)

XREAP2011-04
Moreno-Torres, I. (ACCO, CRES & GiM-IREA)
"Generic drugs in Spain: price competition vs. moral hazard"
(Maig 2011)

XREAP2011-05
Nieto, S. (AQR-IREA)**, Ramos, R.** (AQR-IREA)
"¿Afecta la sobreeducación de los padres al rendimiento académico de sus hijos?"
(Maig 2011)

XREAP2011-06
Pitt, D., **Guillén, M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA)
"Estimation of Parametric and Nonparametric Models for Univariate Claim Severity Distributions - an approach using R"
(Juny 2011)

XREAP2011-07
Guillén, M. (RFA-IREA), **Comas-Herrera, A.**
"How much risk is mitigated by LTC Insurance? A case study of the public system in Spain"
(Juny 2011)

XREAP2011-08
Ayuso, M. (RFA-IREA), **Guillén, M.** (RFA-IREA), **Bolancé, C.** (RFA-IREA)
"Loss risk through fraud in car insurance"
(Juny 2011)

XREAP2011-09
Duch-Brown, N. (IEB), **García-Quevedo, J.** (IEB), **Montolio, D.** (IEB)
"The link between public support and private R&D effort: What is the optimal subsidy?"
(Juny 2011)

XREAP2011-10
Bermúdez, Ll. (RFA-IREA), **Karlis, D.**
"Mixture of bivariate Poisson regression models with an application to insurance"
(Juliol 2011)

XREAP2011-11
Varela-Irimia, X-L. (GRIT)
"Age effects, unobserved characteristics and hedonic price indexes: The Spanish car market in the 1990s"
(Agost 2011)

XREAP2011-12
Bermúdez, Ll. (RFA-IREA), **Ferri, A.** (RFA-IREA), **Guillén, M.** (RFA-IREA)
"A correlation sensitivity analysis of non-life underwriting risk in solvency capital requirement estimation"
(Setembre 2011)

XREAP2011-13
Guillén, M. (RFA-IREA), **Pérez-Marín, A.** (RFA-IREA), **Alcañiz, M.** (RFA-IREA)
"A logistic regression approach to estimating customer profit loss due to lapses in insurance"
(Octubre 2011)

XREAP2011-14
Jiménez, J. L., **Perdiguero, J.** (GiM-IREA), **García, C.**
"Evaluation of subsidies programs to sell green cars: Impact on prices, quantities and efficiency"
(Octubre 2011)

XREAP2011-15
Arespa, M. (CREB)
"A New Open Economy Macroeconomic Model with Endogenous Portfolio Diversification and Firms Entry"
(Octubre 2011)

XREAP2011-16
Matas, A. (GEAP), **Raymond, J. L.** (GEAP), **Roig, J.L.** (GEAP)
"The impact of agglomeration effects and accessibility on wages"
(Novembre 2011)

XREAP2011-17
Segarra, A. (GRIT)
"R&D cooperation between Spanish firms and scientific partners: what is the role of tertiary education?"
(Novembre 2011)

XREAP2011-18
García-Pérez, J. I.; **Hidalgo-Hidalgo, M.**; **Robles-Zurita, J. A.**
"Does grade retention affect achievement? Some evidence from PISA"
(Novembre 2011)

XREAP2011-19
Arespa, M. (CREB)
"Macroeconomics of extensive margins: a simple model"
(Novembre 2011)

XREAP2011-20
García-Quevedo, J. (IEB), **Pellegrino, G.** (IEB), **Vivarelli, M.**
"The determinants of YICs' R&D activity"
(Desembre 2011)

XREAP2011-21
González-Val, R. (IEB), **Olmo, J.**
"Growth in a Cross-Section of Cities: Location, Increasing Returns or Random Growth?"
(Desembre 2011)

XREAP2011-22
Gombau, V. (GRIT), **Segarra, A.** (GRIT)
"The Innovation and Imitation Dichotomy in Spanish firms: do absorptive capacity and the technological frontier matter?"
(Desembre 2011)

2012

XREAP2012-01
Borrell, J. R. (GiM-IREA), **Jiménez, J. L.**, **García, C.**
"Evaluating Antitrust Leniency Programs"
(Gener 2012)

XREAP2012-02
Ferri, A. (RFA-IREA), **Guillén, M.** (RFA-IREA), **Bermúdez, Ll.** (RFA-IREA)
"Solvency capital estimation and risk measures"
(Gener 2012)

XREAP2012-03
Ferri, A. (RFA-IREA), **Bermúdez, Ll.** (RFA-IREA), **Guillén, M.** (RFA-IREA)
"How to use the standard model with own data"
(Febrer 2012)

XREAP2012-04
Perdiguero, J. (GiM-IREA), **Borrell, J.R.** (GiM-IREA)
"Driving competition in local gasoline markets"
(Març 2012)

XREAP2012-05
D'Amico, G., **Guillen, M.** (RFA-IREA), Manca, R.
"Discrete time Non-homogeneous Semi-Markov Processes applied to Models for Disability Insurance"
(Març 2012)

XREAP2012-06
Bové-Sans, M. A. (GRIT), Laguado-Ramírez, R.
"Quantitative analysis of image factors in a cultural heritage tourist destination"
(Abril 2012)

XREAP2012-07
Tello, C. (AQR-IREA), **Ramos, R.** (AQR-IREA), **Artís, M.** (AQR-IREA)
"Changes in wage structure in Mexico going beyond the mean: An analysis of differences in distribution, 1987-2008"
(Maig 2012)

XREAP2012-08
Jofre-Monseny, J. (IEB), **Marín-López, R.** (IEB), **Viladecans-Marsal, E.** (IEB)
"What underlies localization and urbanization economies? Evidence from the location of new firms"
(Maig 2012)

XREAP2012-09
Muñiz, I. (GEAP), **Calatayud, D.**, **Dobaño, R.**
"Los límites de la compacidad urbana como instrumento a favor de la sostenibilidad. La hipótesis de la compensación en Barcelona medida a través de la huella ecológica de la movilidad y la vivienda"
(Maig 2012)

XREAP2012-10
Arqué-Castells, P. (GEAP), **Mohnen, P.**
"Sunk costs, extensive R&D subsidies and permanent inducement effects"
(Maig 2012)

XREAP2012-11
Boj, E. (CREB), **Delicado, P.**, **Fortiana, J**., **Esteve, A.**, **Caballé, A.**
"Local Distance-Based Generalized Linear Models using the dbstats package for R"
(Maig 2012)

XREAP2012-12
Royuela, V. (AQR-IREA)
"What about people in European Regional Science?"
(Maig 2012)

XREAP2012-13
Osorio A. M. (RFA-IREA)**, Bolancé, C.** (RFA-IREA), **Madise, N.**
"Intermediary and structural determinants of early childhood health in Colombia: exploring the role of communities"
(Juny 2012)

XREAP2012-14
Miguelez. E. (AQR-IREA)**, Moreno, R.** (AQR-IREA)
"Do labour mobility and networks foster geographical knowledge diffusion? The case of European regions"
(Juliol 2012)

XREAP2012-15
Teixidó-Figueras, J. (GRIT)**, Duró, J. A.** (GRIT)
"Ecological Footprint Inequality: A methodological review and some results"
(Setembre 2012)

XREAP2012-16
Varela-Irimia, X-L. (GRIT)
"Profitability, uncertainty and multi-product firm product proliferation: The Spanish car industry"
(Setembre 2012)

XREAP2012-17
Duró, J. A. (GRIT), **Teixidó-Figueras, J.** (GRIT)
"Ecological Footprint Inequality across countries: the role of environment intensity, income and interaction effects"
(Octubre 2012)

XREAP2012-18
Manresa, A. (CREB), **Sancho, F.**
"Leontief versus Ghosh: two faces of the same coin"
(Octubre 2012)

XREAP2012-19
Alemany, R. (RFA-IREA), **Bolancé, C.** (RFA-IREA), **Guillén, M.** (RFA-IREA)
"Nonparametric estimation of Value-at-Risk"
(Octubre 2012)

XREAP2012-20
Herrera-Idárraga, P. (AQR-IREA), **López-Bazo, E.** (AQR-IREA), **Motellón, E.** (AQR-IREA)
"Informality and overeducation in the labor market of a developing country"
(Novembre 2012)

XREAP2012-21
Di Paolo, A. (AQR-IREA)
"(Endogenous) occupational choices and job satisfaction among recent PhD recipients: evidence from Catalonia"
(Desembre 2012)

2013

XREAP2013-01
Segarra, A. (GRIT), **García-Quevedo, J.** (IEB), **Teruel, M.** (GRIT)
"Financial constraints and the failure of innovation projects"
(Març 2013)

XREAP2013-02
Osorio, A. M. (RFA-IREA), **Bolancé, C.** (RFA-IREA), Madise, N., Rathmann, K.
"Social Determinants of Child Health in Colombia: Can Community Education Moderate the Effect of Family Characteristics?"
(Març 2013)

XREAP2013-03
Teixidó-Figueras, J. (GRIT), **Duró, J. A.** (GRIT)
"The building blocks of international ecological footprint inequality: a regression-based decomposition"
(Abril 2013)

XREAP2013-04
Salcedo-Sanz, S., **Carro-Calvo, L.**, **Claramunt, M.** (CREB), **Castañer, A.** (CREB), **Marmol, M.** (CREB)
"An Analysis of Black-box Optimization Problems in Reinsurance: Evolutionary-based Approaches"
(Maig 2013)

XREAP2013-05
Alcañiz, M. (RFA), **Guillén, M.** (RFA), **Sánchez-Moscona, D.** (RFA), **Santolino, M.** (RFA), **Llatje, O., Ramon, Ll.**
"Prevalence of alcohol-impaired drivers based on random breath tests in a roadside survey"
(Juliol 2013)

XREAP2013-06
Matas, A. (GEAP & IEB), **Raymond, J. Ll.** (GEAP & IEB), **Roig, J. L.** (GEAP)
"How market access shapes human capital investment in a peripheral country"
(Octubre 2013)

XREAP2013-07
Di Paolo, A. (AQR-IREA), **Tansel, A.**
"Returns to Foreign Language Skills in a Developing Country: The Case of Turkey"
(Novembre 2013)

XREAP2013-08
Fernández Gual, V. (GRIT), **Segarra, A.** (GRIT)
"The Impact of Cooperation on R&D, Innovation andProductivity: an Analysis of Spanish Manufacturing and Services Firms"
(Novembre 2013)

XREAP2013-09
Bahraoui, Z. (RFA); **Bolancé, C.** (RFA); **Pérez-Marín. A. M.** (RFA)
"Testing extreme value copulas to estimate the quantile"
(Novembre 2013)

2014

XREAP2014-01
Solé-Auró, A. (RFA), **Alcañiz, M.** (RFA)
"Are we living longer but less healthy? Trends in mortality and morbidity in Catalonia (Spain), 1994-2011"
(Gener 2014)

XREAP2014-02

Teixidó-Figueres, J. (GRIT), **Duro, J. A.** (GRIT)
"Spatial Polarization of the Ecological Footprint distribution"
(Febrer 2014)

XREAP2014-03
Cristobal-Cebolla, A.; Gil Lafuente, A. M. (RFA), **Merigó Lindhal, J. M.** (RFA)
"La importancia del control de los costes de la no-calidad en la empresa"
(Febrer 2014)

XREAP2014-04
Castañer, A. (CREB); **Claramunt, M.M.** (CREB)
"Optimal stop-loss reinsurance: a dependence analysis"
(Abril 2014)

XREAP2014-05
Di Paolo, A. (AQR-IREA); **Matas, A.** (GEAP); **Raymond, J. Ll.** (GEAP)
"Job accessibility, employment and job-education mismatch in the metropolitan area of Barcelona"
(Maig 2014)

XREAP2014-06
Di Paolo, A. (AQR-IREA); **Mañé, F.**
"Are we wasting our talent? Overqualification and overskilling among PhD graduates"
(Juny 2014)

XREAP2014-07
Segarra, A. (GRIT); **Teruel, M.** (GRIT); **Bové, M. A.** (GRIT)
"A territorial approach to R&D subsidies: Empirical evidence for Catalonian firms"
(Setembre 2014)

XREAP2014-08
Ramos, R. (AQR-IREA); **Sanromá, E.** (IEB); **Simón, H.**
"Public-private sector wage differentials by type of contract: evidence from Spain"
(Octubre 2014)

XREAP2014-09
Bel, G. (GiM-IREA); **Bolancé, C.** (Riskcenter-IREA); **Guillén, M.** (Riskcenter-IREA)**; Rosell, J.** (GiM-IREA)
"The environmental effects of changing speed limits: a quantile regression approach"
(Desembre 2014)

2015

XREAP2015-01
Bolance, C. (Riskcenter-IREA); **Bahraoui, Z.** (Riskcenter-IREA), **Alemany, R.** (Risckcenter-IREA)
"Estimating extreme value cumulative distribution functions using bias-corrected kernel approaches"
(Gener 2015)

XREAP2015-02
Ramos, R. (AQR-IREA); **Sanromá, E.** (IEB), **Simón, H.**
"An analysis of wage differentials between full- and part-time workers in Spain"
(Agost 2015)

XREAP2015-03
Cappellari, L.; **Di Paolo, A.** (AQR-IREA)
"Bilingual Schooling and Earnings: Evidence from a Language-in-Education Reform"
(Setembre 2015)

XREAP2015-04
Álvarez-Albelo, C. D., Manresa, A. (CREB)**, Pigem-Vigo, M.** (CREB)
"Growing through trade: The role of foreign growth and domestic tariffs"
(Novembre 2015)

XREAP2015-05
Caminal, R., Di Paolo, A. (AQR-IREA)
Your language or mine?
(Novembre 2015)

XREAP2015-06
Choi, H. (AQR-IREA)**, Choi, A.** (IEB)
When one door closes: the impact of the hagwon curfew on the consumption of private tutoring in the Republic of Korea

(Novembre 2015)

2016

XREAP2016-01
Castañer, A. (CREB, XREAP); **Claramunt, M M.** (CREB, XREAP), **Tadeo, A.**, **Varea, J.** (CREB, XREAP)
Modelización de la dependencia del número de siniestros. Aplicación a Solvencia II
(Setembre 2016)

XREAP2016-02
García-Quevedo, J. (IEB, XREAP); **Segarra-Blasco, A.** (GRIT, XREAP), **Teruel, M.** (GRIT, XREAP)
Financial constraints and the failure of innovation projects
(Setembre 2016)

XREAP2016-03
Jové-Llopis, E. (GRIT, XREAP); **Segarra-Blasco, A.** (GRIT, XREAP)
What is the role of innovation strategies? Evidence from Spanish firms
(Setembre 2016)

XREAP2016-04
Albalate, D. (GiM-IREA, XREAP); **Rosell, J.** (GiM-IREA, XREAP)
Persistent and transient efficiency on the stochastic production and cost frontiers – an application to the motorway sector
(Octubre 2016)

XREAP2016-05
Jofre-Monseny, J. (IEB, XREAP), **Silva, J. I.**, **Vázquez-Grenno, J.** (IEB, XREAP)
Local labor market effects of public employment
(Novembre 2016)

XREAP2016-06
Garcia-López, M. A. (IEB, XREAP), **Hemet, C.**, **Viladecans-Marsal, E.** (IEB, XREAP)
Next train to the polycentric city: The effect of railroads on subcenter formation
(Novembre 2016)

XREAP2016-07
Vayá, E. (AQR-IREA, XREAP)**, García, J. R.** (AQR-IREA, XREAP)**, Murillo, J.** (AQR-IREA, XREAP)**, Romaní, J.** (AQR-IREA, XREAP)**, Suriñach, J.** (AQR-IREA, XREAP)**,**
Economic impact of cruise activity: the port of Barcelona
(Desembre 2016)

XREAP2016-08
Ayuso, M. (Riskcenter, XREAP)**, Guillen, M.** (Riskcenter, XREAP)**, Nielsen, J. P.**
Improving automobile insurance ratemaking using telematics: incorporating mileage and driver behaviour data
(Desembre 2016)

XREAP2016-09
Ruíz, A. (GEAP, XREAP), **Matas, A.** (GEAP, XREAP), **Raymond, J. Ll.**
How do road infrastructure investments affect the regional economy? Evidence from Spain
(Desembre 2016)

2017

XREAP2017-01
Bernardo, V. (GiM-IREA, XREAP); **Fageda, X.** (GiM-IREA, XREAP)
Globalization, long-haul flights and inter-city connections
(Octubre 2017)

XREAP2017-02
Di Paolo, A. (AQR-IREA, XREAP); **Tansel, A.**
Analyzing Wage Differentials by Fields of Study: Evidence from Turkey
(Octubre 2017)

XREAP2017-03
Melguizo, C. (AQR-IREA, XREAP); **Royuela, V.** (AQR-IREA, XREAP)
What drives migration moves across urban areas in Spain? Evidence from the great recession
(Octubre 2017)

XREAP2017-04
Boonen, T.J., Guillén, M. (RISKCENTER, XREAP); **Santolino, M.** (RISKCENTER, XREAP)
Forecasting compositional risk allocations
(Octubre 2017)

XREAP2017-05
Curto-Grau, M. (IEB, XREAP)**, Solé-Ollé, A.** (IEB, XREAP)**, Sorribas-Navarro, P.** (IEB, XREAP)
Does electoral competition curb party favoritism?
(Novembre 2017)

XREAP2017-06
Esteller, A. (IEB, XREAP)**, Piolatto, A.** (IEB, XREAP)**, Rablen, M. D.**
Taxing high-income earners: tax avoidance and mobility
(Novembre 2017)

XREAP2017-07
Bolancé, C. (RISKCENTER, XREAP), **Vernic, R**
Multivariate count data generalized linear models: Three approaches based on the Sarmanov distribution
(Novembre 2017)

XREAP2017-08
Albalate, D. (GiM-IREA, XREAP)**, Bel-Piñana, P. (**GiM-IREA, XREAP)
Public Private Partnership management effects on road safety outcomes
(Novembre 2017)

XREAP2017-09
Teruel, M. (GRIT, XREAP)**, Segarra, A. (G**RIT, XREAP)
Gender diversity, R&D teams and patents: An application to Spanish firms
(Novembre 2017)

XREAP2017-10
Cuberes, D., **Teignier, M.** (CREB, XREAP)
How Costly Are Labor Gender Gaps? Estimates by Age Group for the Balkans and Turkey
(Novembre 2017)

XREAP2017-11
Murilló, I. P., **Raymond, J. L.** (GEAP, XREAP), **Calero, J.** (IEB, XREAP)
Efficiency in the transformation of schooling into competences: A cross-country analysis using PIAAC data
(Novembre 2017)

XREAP2017-12
Giuntella, O., Mazzonnay, F., Nicodemo, C. (GEAP, XREAP), Vargas Silva, C
Immigration and the Reallocation of Work Health Risks
(Desembre 2017)

XREAP2017-13
Giuntella, O., Nicodemo, C. (GEAP, XREAP), Vargas Silva, C.
The Effects of Immigration on NHS Waiting Times
(Desembre 2017)

XREAP2017-14
Solé-Ollé, A. (IEB, XREAP), Viladecans-Marsal, E. (IEB, XREAP)
Housing Booms and Busts and Local Fiscal Policy
(Desembre 2017)

XREAP2017-15
Jové-Llopis, E. (GRIT, XREAP), Segarra-Blasco, A. (GRIT, XREAP)
Eco-strategies and firm growth in European SMEs
(Desembre 2017)

2018

XREAP2018-01
Teruel, E. (GRIT, XREAP), Segarra-Blasco, A. (GRIT, XREAP)
Gender diversity, R&D teams and patents: An application to Spanish firms
(Febrer 2018)

XREAP2018-02
Palacio, S. M. (GiM, XREAP)
Detecting Outliers with Semi-Supervised Machine Learning: A Fraud Prediction Application
(Abril 2018)

XREAP2018-03
Palacio, S. M. (GiM, XREAP)
Machine Learning Forecasts of Public Transport Demand: A comparative analysis of supervised algorithms using smart card data
(Abril 2018)

XREAP2018-04
Claveria, O. (AQR, XREAP), Monte, E., Torra, S. (RISKCENTER, XREAP)
Tracking economic growth by evolving expectations via genetic programming: A two-step approach
(Octubre 2018)

XREAP2018-05
Bolancé, C. (RISKCENTER, XREAP), Guillén, M. (RISKCENTER, XREAP), Ornelas, A. (RISKCENTER, XREAP)
Alternative methods of estimating the longevity risk
(Octubre 2018)

xarxa.xreap@gmail.com