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An Interval Variables Approach to Address Measurement Uncertainty in Governance Indicators

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Abstract

Many variables in governance are measured with uncertainty. This paper addresses this problem, showing that interval variables are a suitable way to handle it, providing an application in corporate governance. We build two constructs, one for Investor protection and the other for Constraints on shareholders based on the original dataset by La Porta et al. (1998) and we find that for very low levels of investor protection, constraints are a suitable way to provide some form of safeguard. We also provide evidence for the theoretical claim that investor protection and constraints on shareholders work as substitutes under specific circumstances.

Keywords: Corporate Governance, Measurement, Interval Data, Latent Variables.

JEL Codes: G34

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1. Introduction

Measuring governance has been a major endeavor in the last twenty years. This effort has been both methodological and empirical, trying to understand what can be measured, its nature (*de facto* or *de jure*), the degree of subjectivity involved in the measurement. It is fair to say that in several circumstances the indicators are constructed with uncertainty. In this case, building composite indicators in which it is not clear what are the relevant variables in order to measure the latent variable we are interested in may be an appropriate solution.[1] The measurement error that is associated with this uncertainty for the endogenous variable this does not cause estimated coefficients to be biased because the error term catches this additional variation, but the estimation results are weakened due to a low ratio of signal-to-noise, whereas in exogenous variables causes coefficient estimates to be biased and inconsistent (Börsch-Supan and Köke, 2002).

The aim of this paper is to introduce some tools from statistics, namely interval variables and interval regression, that address the problem of uncertainty in governance indicators, and to provide a simple application. The intuition behind it works as follows: suppose we want to measure a governance feature, and we already have some variables in the literature that partially capture that issue; we propose to take all possible combinations of these variables to provide a construct[2] characterizing the feature you are interested in. From each combination we extract a statistical value that captures the commonality among the variables, and then from the different values obtained we build an interval of values between the minimum and the maximum. The uncertainty in measurement may be high or low,

[1] Latent variables, as opposed to observable variables, are variables that are not directly observed but are rather inferred through a mathematical model from other variables that are observed and directly measured.

[2] A construct is the abstract idea, underlying theme, or subject matter that one wishes to measure using survey questions. Some constructs are relatively simple (like political party affiliation), while other constructs are more complex (such as employee satisfaction). Complex constructs contain multiple dimensions or facets that are bound together by some commonality that, as a whole, compose the construct.

depending on the size of this interval. Then we use these intervals to make regressions and establish some statistical relationships between the constructs.[3]

The issue of uncertainty in composite indicators[4] has been highlighted in the literature. Kaufmann et al. (2007) summarize and reply to eleven critiques raised since the inception of the World Bank Governance Indicators (WGI), ranging from comparability across time and space, biases, aggregation, and so on. Thomas (2010) claimed that WGIs lack 'construct validity' under three dimensions. The first is 'content validity', i.e. they are insufficiently grounded in theory; the second is 'convergent validity', i.e. the indicators are correlated with things that theory says they should be correlated with, and finally 'discriminant validity', i.e. the indicators are not correlated with things that theory says they should not be correlated with.[5] Kersting and Kilby (2014) analyzed the impact of foreign aid on democracy using the well-known Freedom House ratings to assess democracy.[6] The

[3] WGIs are provided giving a point estimate and an interval to measure uncertainty. However, as described above the way in which they are calculated is pretty different, and our aim is also to use these intervals to run regressions between these constructs in order to take into account this uncertainty when establishing empirical regularities.

[4] A general reference on the topic is OECD (2008).

[5] Kaufmann et al. (2010) replied that these criteria are of dubious value to assess the quality of empirical measures because they would cause confirmatory biases in the empirical analysis using these indicators.

[6] The overall rating is an average of two sub-ratings, Civil Liberties (CL rating) and Political Rights (PR rating). Each is reported on a seven-point scale, with 1 denoting the fewest restrictions (the best rating) and 7 denoting the most restrictions (the worst rating). The CL rating is based on a more fine-grained Civil Liberties score (CL score) generated from responses to a check-list of 15 questions in four categories (Freedom of Expression & Belief; Associational & Organizational Rights; Rule of Law; and Personal Autonomy & Individual Rights). Answers to each question assign a score from 0 (less free) to 4 (more free) so that the CL score ranges from 0 to 60. The PR rating is based on a Political Rights score (PR score) generated from responses to a 10 question check-list so PR score ranges from 0 to 40. The ranges of CL score corresponding to the 7 ratings are 0–7, 8–16, 17–25, 26–34, 35–43, 44–52, 53–60 and for PR score 0–5, 6–11, 12–17, 18–23, 24–29, 30–35, 36–40. This approach differs from ours since here the intervals are taken from the already known building blocks of the indices, whereas our intervals are created from a statistical procedure that builds constructs starting from a number of variables for which we do not have underlying intervals.

employed an interval regression to account for Freedom House's method of rating countries and found a significant positive relationship in 122 countries between 1972 and 2011.

The paper is organized as follows: first, we introduce interval variables, and then we apply this method to the well-established dataset on law and finance provided by La Porta et al. (1998). We provide two constructs, one for investor protection and another for constraints on minority shareholders, and we show that for the subsample of low investor protection countries, there is a negative relationship between them, which we interpret as constraints substituting for investor protection. In the last section we provide some conclusive remarks.

2. Interval variables

To represent complex concepts in governance we need to design some appropriate statistical tools as the composite indicators (Freudenberg, 2003). However, we are not sure which indicators specifically use to adequately represent the concepts, therefore we face an uncertainty problem. For this reason, we propose to take all the composite indicators given by the possible combinations of the variables. Furthermore, since using the mean, the median or a function to aggregate these data clearly leads to an information loss (Diday, 2013), we consider an approach that explicitly takes into account the variation in data, such as interval data (Billard, 2008; Drago, 2014, Drago and Gesuele (2014).

Starting with c composite indicators with $c = 1, \dots C$ and k constructs with $k = 1, \dots . K$, we build the interval variable by considering different representations of the single composite indicator:

$$I[Y]^c = [\underline{Y_k^c}, \overline{Y_k^c}] \qquad (1)$$

Where $\underline{Y_k^c}$ and $\overline{Y_k^c}$ are the lower and the upper bounds of the interval.

There are various statistical approaches to build composite indicators (for a review see Nardo et al., 2005), we consider the outcomes from the Principal Component Analysis[7] (PCA thereafter). The advantage of PCA is that we do not need to consider a specific weighting of the various constructs that can lead to very different results. We start from the data matrix and we perform each PCA, then the results from the PCA analysis are considered.[8]

Before building a unique construct we need to test its internal consistency whose measure is based on the correlations of the different variables adopted.. In other words, we need to detect whether different variables can lead to the construction of a single unidimensional construct. To do so, for each group of variables we calculate the Cronbach alpha (Cronbach, 1951; Nardo et al., 2005):

$$\alpha_c = \left(\frac{Q}{Q-1}\right)\frac{\sum_{i\neq j} cov(x_i,x_j)}{var(x_0)} \quad c = 1 \dots C \; ; \; i,j = 1 \dots Q \qquad (2)$$

Where c are the constructs, Q is the number of the different indicators considered at the start of the measurement process, x_i and x_j are two indicators considered in the construction of the latent variable, and x_0 is the sum of all the indicators considered in building the construct. A group of variables is considered if the Cronbach alpha is around 0.80. This number is established in literature as the relevant one in order to obtain a single principal component in the data matrix (Tavakol and Dennick 2011). The groups of variables used in the measurement of the construct that show a low Cronbach alpha are discarded. The constructs obtained in this way are considered for the interval of values.

[7] For a complete reference to the principal component analysis, see Jolliffe (2002).

[8] A very important point in the construction of the composite indicators is that the results can heavily depend on the weights that are chosen (Freudenberg, 2003).

Every PCA needs to extract the first component, since this is the most informative to measure the latent construct. The other components (eigenvalue criterion smaller than one) are less informative than the original variables (Gherghi and Lauro, 2004). Therefore, for each composite indicator *c* we will consider all the possible specifications *k* and so we obtain a different outcome for the composite indicator Y_k^c .

2.1 The interval variables characteristics of the constructs

The different composite indicators represent the uncertainty in measuring the complex concept. We can usefully represent this complexity as an interval variable, which can be characterized by its lower and upper bounds, while other characteristics of the intervals of the constructs are the centers and the radii. Being *c* the constructs considered and *k* the interval variables obtained, we can have:

$$Y_{center,k}^c = \frac{1}{2}(\underline{Y_k^c} + \overline{Y_k^c}) \qquad (3)$$

Where $\underline{Y_k^c}$ and $\overline{Y_k^c}$ are the lower and the upper bound of the constructs, respectively. The center can be defined as the central measure of the interval considered, the measure to compare different interval variables *k*. The center is not the only measure that we can consider. It is also possible to take into account a measure of the variation between the two bounds, the radius of the interval and the upper and the lower bounds. With the same notation above, we have:

$$\mathrm{Y}_{\mathrm{radius,k}}^{\mathrm{c}} = \frac{1}{2}(\underline{\mathrm{Y}_{\mathrm{k}}^{\mathrm{c}}} - \overline{\mathrm{Y}_{\mathrm{k}}^{\mathrm{c}}}) \qquad (4)$$

The radius of the interval shows the variation in the interval. With respect to the center, it allows to analyze the variation of the measures obtained by considering the constructs.

2.2 Interval regression

We can now consider some basic statistical methods to analyze the interval indicators we have previously constructed. Following Lauro and Gioia (2005), the mean of the interval variable is:

$$M = \left[\frac{1}{n}\sum_{i=1}^{n}\underline{Y}\,;\frac{1}{n}\sum_{i=1}^{n}\overline{Y}\right] = \left[\underline{M};\overline{M}\right] \qquad (5)$$

Where $\underline{Y}$ is the lower bound of the interval variable measured for the different observations and $\overline{Y}$ is the upper bound. The interval variables are obtained for each observation (for example different measurements of the latent variable for each country). Here the mean M is the average of the intervals, with $\underline{M}$ the lower bound and $\overline{M}$ is the upper bound.

The linear regression model is the most frequently used form in interval regression analysis for expressing the relationship between one or more explanatory variables and response. For the sake of simplicity, the case of simple linear regression model involving a single independent variable is considered, which can be easily generalized to the case of multiple inputs, although computationally more complex.

The objective of the interval regression is to determine a functional linear relationship:

$$Y = A_0 \oplus A_1 \otimes X \qquad (6)$$

where Y is the interval model output, X the interval model input and A_0 and A_1 the interval parameters, i.e. unknowns to be estimated from interval data.

The coefficients of the model can be estimated by applying the classical model to the mid-point of the intervals (Billard (2008), Billard and Diday (2000), Arroyo et al. (2010) and Lima-Neto et al. (2006)).[9] The estimation of the parameters may be obtained by an adaptation of the solution obtained by the Least Square estimation method for the classical linear model, where relevant definitions of variance and covariance are used.

3. An application to the law and finance literature

In their seminal contribution, La Porta et al. (1998) examine legal rules covering protection of corporate shareholders and creditors, the origin of these rules, and the quality of their enforcement in 49 countries. They show that common law countries generally have the strongest legal protections of investors, with German and Scandinavian civil law countries located in the middle, and French civil law countries at the bottom. Moreover, concentration of ownership of shares in the largest public companies is negatively related to investor protections. Do these countries have other, *substitute* mechanisms of corporate governance?

One potential adaptation to fewer laws is strong enforcement of laws, but as we pointed out above this does not appear to be the case empirically. Another adaptation to legally introduce mandatory standards of retention and distribution of capital to investors, which limit the opportunities for managerial expropriation. Only French civil law countries have mandatory dividends, and German civil law countries are the most likely to have legal reserve requirements of all the legal families. A further response to the lack of legal protections is high ownership concentration since some concentration of ownership is typically efficient to provide managers with incentives to work, and large investors with

[9] For the sake of simplicity, we only refer and apply this method. However, other approaches are available in the literature, for example: the Center and Range Method (Lima-Neto and de Carvalho, 2008), the Constrained Centre and Range Method (Lima-Neto and de Carvalho, 2010), and the Bivariate Symbolic Method (Lima-Neto et al., 2011).

incentives to monitor them (Jensen and Meckling 1976, Shleifer and Vishny 1986). However, some dispersion of ownership is also desirable to diversify risk. As argued by Shleifer and Vishny (1997), very high ownership concentration may be a reflection of poor investor protection. La Porta et al. (1998) find a strong negative correlation between concentration of ownership, measured by the combined stake of the three largest shareholders, and the quality of legal protection of investors. They claim that data on ownership concentration supports the idea that legal systems matter for corporate governance, and that firms have to adapt to the limitations of the legal systems in which they operate.

The aim of the application is to analyze the relationship between investor protection and constraints. Both are measured with uncertainty, therefore, we use intervals data in order to capture this aspect. The first step in the analysis is considering the dataset of La Porta et al. (1998) to measure investor protection and constraints on shareholders. We consider two sets of variables in order to measure the relevant concept, by applying to the entire set of variables the Cronbach alpha, obtaining both constructs and latent variables from the initial indicators. Construct 1 is built from rule of law, efficiency of the judicial system, repudiation of contracts by government, expropriation risk, accounting standards. Construct 2 comes from extraordinary shareholders' meeting votes, mandatory dividend, ownership of 10 largest private firms and legal reserves. The appendix reports the definitions and the sources of the original variables. Then we perform a principal component analysis on the set of the variables considered by applying the criterion of the eigenvalue value (Gherghi and Lauro, 2004) one for each group of variables, and then we obtain the intervals by considering the values obtained in the procedure. Tables 1 and 2 show the intervals, the centers and the radii of each construct.

[Table 1 about here]

[Table 2 about here]

The coefficients of the regression line are estimated through the mid-point approach outlined above. More specifically, we regress the interval variables for the investor protection and the constraints on shareholders considering two groups of intervals: higher and lower investor protection (calculated with respect to the mean of the investor protection). To perform the interval regression, we take the midpoints of each interval variable.[10]

We find that for high levels of investor protection the estimated coefficient is not statistically significant, whereas there is a positive and statistically significant relationship for countries with low values of investor protection making constraints work as a substitute for explicit regulations for investor protection, an issue already addressed by La Porta et al. (1998).

[Table 3 about here]

Graphically, each observation is represented by a rectangle, which embodies the uncertainty in measuring each variable, since the value lies between a high and a low value. Figures 1 and 2 report the regression line previously estimated and the observations.

[Figure 1 about here]

[Figure 2 about here]

[10] We perform the computations on R language with the RSDA package (Rodriguez et al., 2014).

4. Conclusions

This paper has suggested the use of interval variables as an effective way to deal with uncertainty in measuring corporate governance variables. This uncertainty may come from a number of sources: lack of a theoretical foundation on how to measure a certain variable, measurement errors in both left- and right-hand side variables, etc. Interval variables depart from the measurement of a single variable and allow building constructs obtained from different variables measuring a similar phenomenon. Interval variables explicitly take this uncertainty into account and, depending on the way in which they are built, can provide different results contingent to the approach followed. The center of the interval can be considered as the value that represents more likely the "real" value, and the size of the interval is a measure of the uncertainty.

We apply this methodology the well-known La Porta et al. (1998) dataset on law and finance. We build two constructs (one for investor protection and the other for constraints on shareholders) and we find that in a bivariate interval regression constraints work as a substitute for investor protection in countries in which the latter is small. Clearly, these results are very simple and do not come from a full-size econometric model in which several covariates are included. In any case we have provided a primer on the use of a statistical tool that may address some important issue in governance measurement.

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TABLE 1 - Construct 1: Investor protection

Country	Lower Bound	Upper Bound	Center	Radius
Argentina	-2.16	-1.60	-1.88	0.28
Australia	1.45	1.86	1.66	0.20
Austria	1.79	2.16	1.97	0.18
Belgium	1.73	2.10	1.91	0.19
Brazil	-1.09	-0.70	-0.89	0.20
Canada	1.50	1.91	1.71	0.20
Chile	-0.59	-0.28	-0.43	0.15
Colombia	-1.63	-0.72	-1.18	0.46
Denmark	1.81	2.17	1.99	0.18
Ecuador	-1.75	-0.98	-1.36	0.39
Egypt	-1.82	-1.44	-1.63	0.19
Finland	1.76	2.12	1.94	0.18
France	1.13	1.59	1.36	0.23
Germany	1.61	2.02	1.81	0.21
Greece	-0.87	-0.65	-0.76	0.11
Hong Kong	0.79	1.35	1.07	0.28
India	-1.18	-0.53	-0.86	0.32
Indonesia	-2.52	-1.44	-1.98	0.54
Ireland	0.97	1.37	1.17	0.20
Israel	-0.38	0.66	0.14	0.52
Italy	0.60	1.33	0.97	0.36
Japan	1.72	2.08	1.90	0.18
Jordan	-2.17	-1.08	-1.62	0.55
Kenya	-1.95	-1.48	-1.72	0.23
Malaysia	-0.10	0.29	0.10	0.20
Mexico	-1.21	-0.95	-1.08	0.13
Netherlands	1.94	2.29	2.11	0.18
New Zealand	1.81	2.17	1.99	0.18
Nigeria	-2.97	-2.10	-2.53	0.43
Norway	2.03	2.36	2.19	0.17
Pakistan	-2.93	-2.49	-2.71	0.22
Peru	-2.83	-2.19	-2.51	0.32
Philippines	-3.20	-2.65	-2.93	0.27
Portugal	0.11	1.04	0.58	0.46
Singapore	1.26	1.63	1.45	0.19
South Africa	-1.44	-0.98	-1.21	0.23
South Korea	-0.68	0.10	-0.29	0.39
Spain	0.13	1.02	0.58	0.45
Sri Lanka	-2.59	-1.74	-2.16	0.42
Sweden	1.80	2.16	1.98	0.18
Switzerland	2.07	2.47	2.27	0.20
Taiwan	0.56	1.28	0.92	0.36
Thailand	-1.53	-0.37	-0.95	0.58
Turkey	-1.94	-1.29	-1.61	0.32
UK	1.64	2.00	1.82	0.18
US	1.82	2.18	2.00	0.18
Uruguay	-1.29	-0.83	-1.06	0.23
Venezuela	-1.18	-0.85	-1.02	0.17
Zimbabwe	-2.43	-1.63	-2.03	0.40

TABLE 2 - Construct 2: Constraints

Country	Lower Bound	Upper Bound	Center	Radius
Argentina	0.12	0.44	0.28	0.16
Australia	-1.67	-1.47	-1.57	0.10
Austria	-0.18	0.12	-0.03	0.15
Belgium	0.12	0.55	0.33	0.21
Brazil	1.87	2.20	2.04	0.17
Canada	-1.67	-1.47	-1.57	0.10
Chile	1.41	1.50	1.45	0.04
Colombia	3.17	3.72	3.44	0.28
Denmark	0.50	0.60	0.55	0.05
Ecuador	3.17	3.72	3.44	0.28
Egypt	1.24	1.40	1.32	0.08
Finland	-0.23	-0.20	-0.22	0.01
France	0.06	0.12	0.09	0.03
Germany	-0.18	0.12	-0.03	0.15
Greece	1.73	2.09	1.91	0.18
Hong Kong	-1.47	-1.43	-1.45	0.02
India	-1.47	-1.43	-1.45	0.02
Indonesia	-0.23	-0.20	-0.22	0.01
Ireland	-1.47	-1.43	-1.45	0.02
Israel	-1.47	-1.43	-1.45	0.02
Italy	0.44	0.84	0.64	0.20
Japan	0.17	0.60	0.38	0.22
Jordan	0.60	1.23	0.91	0.31
Kenya	-1.47	-1.43	-1.45	0.02
Malaysia	-1.47	-1.43	-1.45	0.02
Mexico	0.44	1.47	0.95	0.51
Netherlands	-0.23	-0.20	-0.22	0.01
New Zealand	-1.67	-1.47	-1.57	0.10
Nigeria	-1.47	-1.43	-1.45	0.02
Norway	0.36	0.44	0.40	0.04
Pakistan	-1.47	-1.43	-1.45	0.02
Peru	0.44	0.84	0.64	0.20
Philippines	-0.20	-0.18	-0.19	0.01
Portugal	0.12	0.44	0.28	0.16
Singapore	-1.47	-1.43	-1.45	0.02
South Africa	-1.67	-1.47	-1.57	0.10
South Korea	1.00	1.40	1.20	0.20
Spain	0.12	0.44	0.28	0.16
Sri Lanka	-1.47	-1.43	-1.45	0.02
Sweden	0.36	0.44	0.40	0.04
Switzerland	1.24	1.40	1.32	0.08
Taiwan	2.37	3.01	2.69	0.32
Thailand	-1.14	-0.66	-0.90	0.24
Turkey	0.36	0.44	0.40	0.04
UK	-1.47	-1.43	-1.45	0.02
US	-1.47	-1.43	-1.45	0.02
Uruguay	1.15	1.54	1.34	0.20
Venezuela	0.12	0.55	0.33	0.21
Zimbabwe	-1.67	-1.47	-1.57	0.10

TABLE 3 - Estimation

	Model 1: Low Protection	Model 2: High Protection
Intercept	-1.668**	1.508***
	(0.137)	(0.137)
Constraints	0.216†	0.095
	(0.087)	(0.122)
Adjusted R^2	0.197	-0.017
F-statistic	6.048**	0.596

FIGURE 1 – High protection

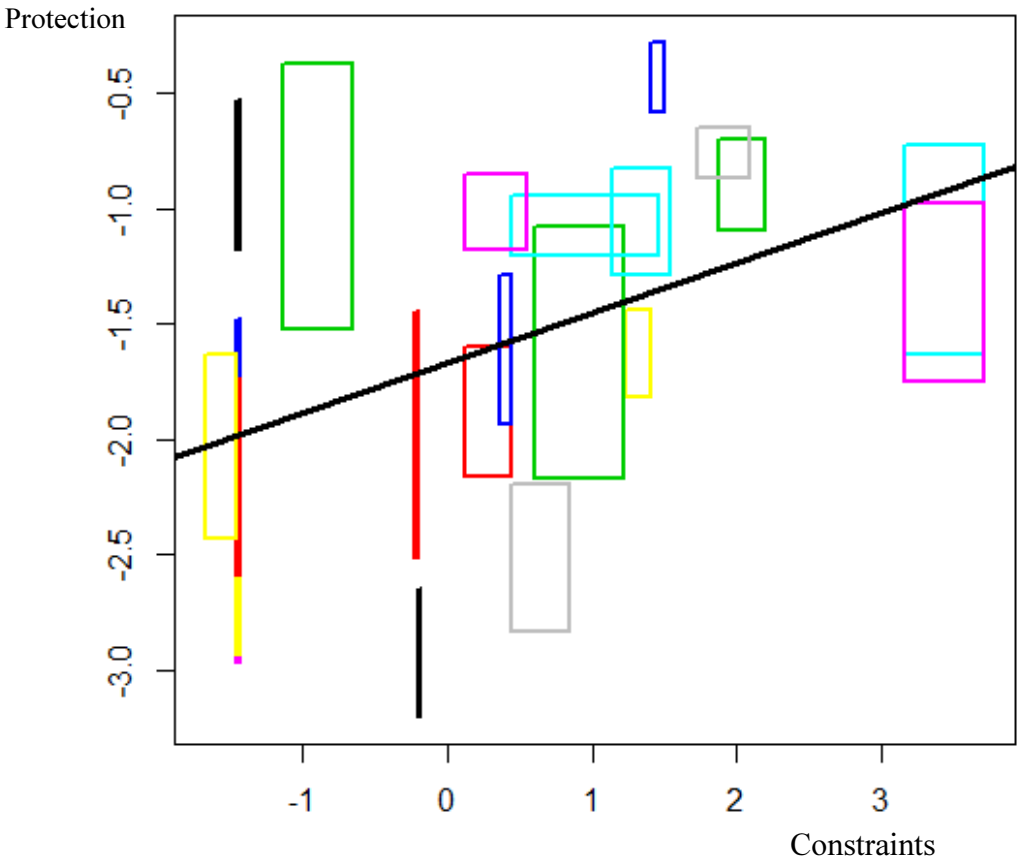
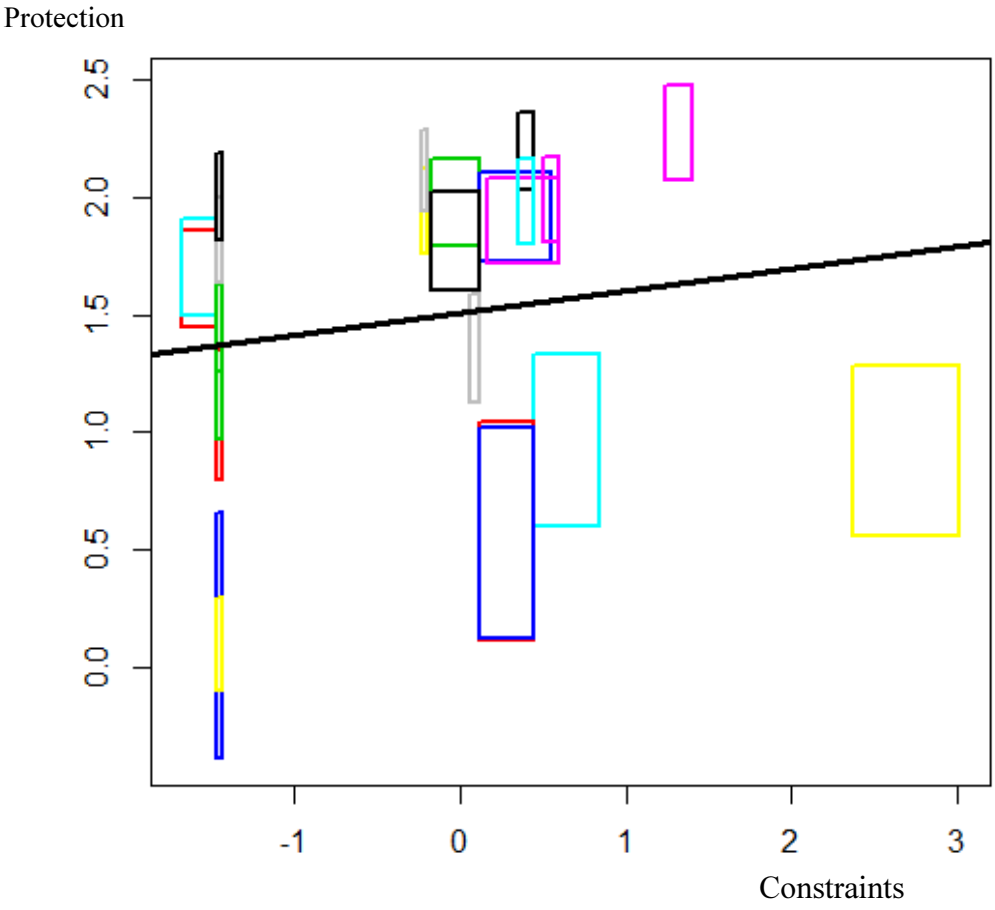


FIGURE 2 – Low protection



APPENDIX

Components of Construct 1	
Rule of law	Assessment of the law and order tradition in the country produced by the country-risk rating agency *International Country Risk* (ICR). Average of the months of April and October of the monthly index between 1982 and 1995. Scale from 0 to 6, with lower scores for less tradition for law and order.
Efficiency of the judicial system	Assessment of the "efficiency and integrity of the legal environment as it affects business, particularly foreign firms" produced by the country-risk rating agency *Business International Corporation.* It "may be taken to represent investors' assessments of conditions in the country in question". Average between 1980-1983. Scale from 0 to 10, with lower scores lower efficiency levels.
Repudiation of contracts by governments	ICR's assessment of the "risk of a modification in a contract taking the form of a repudiation, postponement, or scaling down" due to "budget cutbacks, indigenization pressure, a change in government, or a change in government economic and social priorities." Average of the months of April and October of the monthly index between 1982 and 1995. Scale from 0 to 10, with lower scores for higher risks.
Risk of expropriation	ICR's assessment of the risk of "outright confiscation" or "forced nationalization". Average of the months of April and October of the monthly index between 1982 and 1995. Scale from 0 to 10, with lower scores for higher risks.
Accounting standards	Index created by examining and rating companies' 1990 annual reports on their inclusion or omission of 90 items. These items fall into 7 categories (general information, income statements, balance sheets, funds flow statement, accounting standards, stock data and special items). From International Accounting and Auditing Trends, Center for International Financial Analysis & Research, Inc.
Components of Construct 2	
Extraordinary Shareholders' Meeting Votes	Percentage of share capital to call an extraordinary shareholders' meeting It is the minimum percentage of ownership of share capital that entitles a shareholder to call for an Extraordinary Shareholders' Meeting.
Mandatory dividend	Equals the percentage of net income that the Company Law or Commercial Code requires firms to distribute as dividends among ordinary stockholders. It takes a value of zero for countries without such restriction.
Ownership of 10 largest private firms	The average percentage of common shares owned by the three largest shareholders in the ten largest non-financial, privately-owned domestic firms in a given country. A firm is considered privately owned if the State is not a known shareholder in it.
Legal reserves	It is the minimum percentage of total share capital mandated by Corporate Law to avoid the dissolution of an existing firm. It takes a value of zero for countries without such restriction.