Drivers of Sovereign Recovery Risk

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Abstract

What determines the recovery of sovereign bond holders in the face of a credit event? This paper studies empirical determinants for sovereign recovery risk. Guided by theoretically backed hypotheses we use a sample of 102 past restructurings and empirically test the relation between haircut sizes and their economic drivers. We find a significant linkage of the haircut size to a debtor's ability to repay as well as his willingness. Distinguishing between excusable and strategic defaulters in a new way enables us to empirically show that punishment is of markedly increased effectiveness amongst the strategic cohort. Based on these results we develop a forecasting-model for predicting haircuts conditional on the restructurings taking place within the year ahead and assess the performance of the model by applying it to a sample of the 45 restructurings observed from 1991 to present.

Keywords: Sovereign debt, sovereign recovery risk.

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1 Introduction

What determines the recovery of sovereign bond holders in the face of a credit event? While most of the literature on assessing sovereign credit risk is concerned with the properties of default arrivals an equally central ingredient is the magnitude of the losses in case the creditors' claims are not met, i.e. the loss given default (LGD). With a tremendous growth of sovereign debt levels all over the world, understanding the economic underpinnings not only of default rates (PD) but also of recovery rates should be an important concern for market participants and policy-makers. This paper attempts to contribute to this issue.

A broad literature offers more or less persuasive explanations of why sovereign countries repay their debts and what motivates creditors to provide funding in the first place. Besides the fear of market exclusion and the threat of direct punishments[1], several recent papers focus on spillover-effects on the domestic economy.[2] Indeed, empirical evidence suggests that defaulters are restricted in accessing international capital markets but restriction seems rather short lived and also direct sanctions appear to play a minor role. In contrast, the magnitude of spillover effects can be considerable. Given this evidence, we can draw conclusions on the conditions that lead debtors to default and thus on the likelihood of a default.

What is less clear both from a theoretical and an empirical perspective is what determines recovery in default. Theoretical models on sovereign default often simply assume constant or even zero recovery. Noteworthy exceptions[3] are the models incorporating endogenous debt renegotiations such as Benjamin and Wright (2009) and Yue (2010). In these models, recovery rates as outcomes of such bargaining games are naturally driven by threat points and bargaining power of the involved parties. However, we are not aware of any empirical study that is concerned with analyzing determinants of sovereign recovery rates within a comprehensive framework. We address this issue.

[1] See, for example, Eaton and Gersovitz (1981) and Bulow and Rogoff (1989).

[2] See, for example Gennaioli et al. (2014).

[3] Basu (2009) also regards haircuts that are linked to fundamentals, however he doesn't regard a negotiation process.

Our study takes as a starting point Cruces and Trebesch (2013), who present a new database of haircut estimates and show that large sovereign haircuts are associated with adversely higher subsequent borrowing costs. We go one step ahead and use their dataset to investigate the linkage between haircuts and proxies for the bargaining position of the parties involved. We find significant empirical evidence that it is crucial for the size of the haircut (a) whether a default is perceived as rather for excusable or strategic reasons, (b) how the creditors judge the future debt handling ability of the debtor, and (c) to what extend the debtor is affected by punishment mechanisms consequencing default. Finally, we use our results to develop a forecasting model for LGDs of restructurings conditional on the restructuring taking place in the respective year ahead. In an out-of-sample study, we test this model by applying it to 45 haircuts for restructurings observed from 1991 to present and reach an R^2 of 0.52.

Our paper complements the literature in several ways. First, it contributes to the growing literature on empirical determinants of sovereign yield spreads. This includes Boehmer and Megginson (1990), Duffie et al. (2003), Pan and Singleton (2008), Hilscher and Nosbusch (2010), and Longstaff et al. (2011). Their focus is on the economic underpinnings of the sovereign yield spreads as a whole. Only Pan and Singleton (2008) consider the recovery of sovereign bond holders in the face of a credit event as we do. We add to this literature by analyzing the drivers of sovereign haircuts based on a complete set of sovereign restructuring events over the last forty years, offering interesting new insights.

Second, we provide empirical evidence for the recent discussion focusing on the importance of spillover effects as a consequence of default. Current work on this issue includes Trebesch (2009) who empirically shows that aggressiveness in sovereign debt policies goes along with a decline in domestic corporate access to external finance. Further, Brutti (2011) investigates the variation of spillover effects across different industry sectors and shows that spillovers increase with a sector's dependence on external financial resources. Basu (2009) and Gennaioli et al. (2014) both examine spillover effects towards the financial sector. Basu

(2009) shows in an entirely theoretical context that if a debtor cannot discriminate foreign bond holders a higher public debt exposure by the domestic financial sector results in lower haircuts in equilibrium. Gennaioli et al. (2014) develop a model which shows that the better financial institutions within a country the severer the spillover effects consequencing sovereign default. We provide empirical evidence for a clear link between spillover effect and haircut sizes and find the reasons for the default to have a moderating effect.

Third, our paper contributes to studies that seek to understand the stochastic nature of recovery rates on the basis of past defaults. While other papers such as Altman and Kishore (1996), Altman et al. (2005), Acharya et al. (2007), and Jankowitsch et al. (2014) analyze private debt, ours is the first to address the determinants of sovereign recovery rates. Sovereign debt differs from corporate or bank debt in at least two important aspects. First, sovereign debt is typically not secured by specific collateral. Second, sovereign creditors cannot go to court to enforce debt repayment. For corporate debt it is precisely the ranking of an obligation, the assets securing it, and the nature of the bankruptcy code together with the jurisdiction under which the borrower operates that strongly affects recovery in default (see also Davydenko and Franks (2008)). This makes it all the more important to provide an independent and comprehensive empirical examination of sovereign recovery rates.

The remainder of this paper is outlined as follows: In Section 2 we develop our hypotheses. Section 3 describes the variables we use to check whether or not there is empirical evidence for the hypotheses. We present the results from our empirical examinations in Section 4. Eventually we analyze the out-of-sample performance of our model by forecasting haircuts in Section 5. We conclude in Section 6.

2 Institutional background and hypotheses development

2.1 Default and restructuring process

To guide our empirical exercise of predicting sovereign recovery rates, we first introduce the stylized setting of a sovereign default. Figure 1 illustrates a typical timeline for a default and restructuring process. Sometimes the default is preceded by a distress phase, however

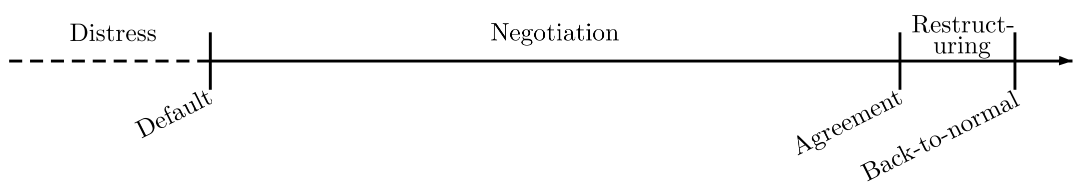


Figure 1: Stylized timeline of a sovereign default and restructuring

this is not mandatory.[4] Independent of the existence of this phase, the default starts by the sovereign failing to serve an outstanding external debt obligation or officially announcing that it is planning to do so at some future point in time.[5] Following default, a negotiation between the creditors and the sovereign is started. Subject of the negotiation is a new debt instrument which is to replace the defaulted debt. After agreement upon the characteristics of the replacing instrument, the referring debt is restructured and sovereign funding can go on in the usual manner.

2.2 Hypotheses development

The theoretical literature on sovereign default often simply assumes an exogenously given recovery rate. Thus, this literature is silent on the determinants of haircuts. In contrast, a small but growing literature derives the haircut as either an outcome of a bargaining process

[4]Sometimes there is no actual default as well, meaning restructurings are initiated before such an event. For our economic interpretations, however, this doesn't make any difference, since in those cases we would set the starting point to the beginning of restructuring negotiations.

[5]This is usually linked to some kind of serious commitment by the sovereign, since the announcement alone has intense negative effects on the financing capability of the entity.

between the sovereign entity and his creditors, such as Benjamin and Wright (2009) and Yue (2010), or as the sovereign's optimal decision in equilibrium like Basu (2009). Although these models vary according to their detailed derivation of the haircuts, at a basic level we can conclude at least three things: First, the sovereign's ability to repay (in those models represented by the endowment or productivity process) is an important determinant of the sovereign's outside option. Second, beyond the ability to repay, punishment mechanisms due to default matter. Third, both the magnitude of these punishment mechanisms and their effectiveness crucially depend on the sovereign's reason to default.

The main stochastic driver of a sovereign debt model is some economic endowment, productivity, or output variable characterizing the country's technology. This state variable naturally governs the sovereign's ability to repay in case of a default. Ceteris paribus, a higher ability to repay should be associated with higher debt repayments leading to our first hypothesis:

Hypothesis 1 ***Debtor's ability to repay matters.*** *The debtor's (estimated) ability to serve future obligations is influencing the size of the haircut. The higher the ability the lower the haircut.*

Another important driver within a sovereign debt model refers to the drawbacks from staying in default mirrored by the punishment mechanisms as a consequence of default. The theoretical literature considers the fear of market exclusion following the Eaton and Gersovitz (1981) approach, or direct sanctioning, and more recently spillover effects on the private sector. Spillovers often refer to the decline of corporate access to external finance following default as examined by Trebesch (2009) or Gennaioli et al. (2014). Within the latter approach default weakens the balance sheet of financial institutions who hold sovereign bonds and as a result private credit declines. Whatever the punishment channel is, the incentive to quickly reach an agreement should be stronger for higher associated cost of default, leading to our second hypothesis:

Hypothesis 2 ***Severity of punishment matters.*** *The more intense the threat of punishment a debtor faces in case of default the lower the haircut. If a debtor is exposed to stronger punishment, his incentives to quickly reach an agreement increase.*

The magnitude of these punishment mechanisms and their effectiveness is likely to depend on the type of default. Indeed, lenders differentiating different types of defaulters are already considered in Grossman and Huyck's (1988) reputational equilibrium model as well as in Cole and Kehoe (1998), Trebesch (2009) and Tomz (2011). Let us abstract two different types of default: (i) Excusable ones which could be due to a natural catastrophe, a war, or a black swan shock to the debtor's economy. (ii) Strategic defaults, which from an external point of view appear to be unwarranted and seem to be mainly driven by the greediness of the defaulting entity. Now consider the punishment via the market exclusion channel. Contrary to the common assumption amongst most theoretical models that there is complete market exclusion as a consequence of default, in reality market access might be restricted but not impossible. Defaulters might be able to lessen the negative effects of punishments, subject to certain conditions, e.g. via third party provision of concessional debt[6]. In particular, it is very likely for excusable defaulters to have a broader access to concessional debt markets mainly because third parties have incentives to guarantee their survival (e.g. to secure a minimum welfare level for humanitarian reasons).

Beyond the channel of third party debt provision, variation of punishment severity should not influence an excusable defaulter's bargaining position, since his hands are tight. In a theoretical bargaining framework his position would be characterized by an external secured minimum level of his outside option payoff via the provision of third party debt. Since an excusable defaulter's wealth is close to that minimum, punishment is non effective. In contrast, wealth of a strategic defaulter is expected to be far above the minimum level and therefore punishment indeed affects his outside option payoff. Consistently, we should

[6]The regard of this additional debt market is in line with Boz (2011) who also considers a concessional debt market, however not distinguishing a defaulter's type.

observe a negative relationship between punishment severity and haircut sizes, leading to our third hypothesis:

Hypothesis 3 ***Default type matters.*** *Strategic defaults differ from excusable defaults in a way that the associated haircuts are lower mainly because the willingness dimension is relevant, too.*

To test whether and to which extend these hypotheses hold, our empirical study focuses on the linkage between sovereign haircut sizes and proxies for the different dimensions under investigation across countries and over time.

3 Variable choices and data description

3.1 Dataset and timing

Table A1 in the Appendix gives a detailed overview of the definitions and sources for the variables we use within our analyses. We perform all our analyses on a yearly basis. Precisely, we take the vector of values of the explanatory variables (which we will define on a case by case basis) at a pre-restructuring date and link them to the corresponding haircut. We use the most recent values that are available before the end of the respective restructuring, e.g. if a restructuring date was 05/1990, we take the values of the explanatory variables by the end of 1989 since our data is available on a yearly basis. Thereby, we always consider a lag less than one year. We refer to this lag as $t = -1$ within our following examinations ($t = -2, .., -7$ are defined analogously). Whenever we use a lag other than $t = -1$, we will particularly indicate that we do so.

3.2 Haircut measure

As left hand side variable for our empirical analyses we use a haircut measure introduced by Sturzenegger and Zettelmeyer (2005):

$$hsz_i^t = 1 - \frac{NPV(new\ debt, r_i^t)}{NPV(old\ debt, r_i^t)}. \tag{1}$$

The discount rate r_i^t denotes the secondary market yield for the country i extrapolated from the replacing debt instrument on the first trading day t following the debt exchange also referred to as exit yield. Contrary to the traditional approach of assessing haircuts by observing the present value of the new debt relative to the face value of the outstanding debt, which has been and partly still is common amongst practitioners, hsz also accounts for the temporal structure of the old credit.[7] We use a hsz dataset provided by Cruces and Trebesch (2013) for our analyses. They calculate the measure for 180 external debt restructurings covering the period from 1970 to 2010. The dataset is complete, including all sovereign debt restructurings involving medium- and long-term debt by foreign commercial creditors within this period. Private-to-private debt exchanges as well as non-distressed debt exchanges, which are part of routine liability management, are excluded. Cruces and Trebesch (2013) provide a detailed case-by-case description of their sources in their online appendix. The haircut is reported by the month the restructuring is completed.

Since the measure commonly lies in the $(0, 1)$ interval[8] the application of standard linear regression techniques would be misleading. To address this problem, we make use of a beta-regression model according to Cribari-Neto and Ferrari (2004) and thereby follow e.g. Renault and Scaillet (2003) and Gupton and Stein (2010) who also assume beta-distributed haircuts. By applying this methodology the connection between the haircuts and the explanatory variables is drawn via a link-function g. In our standard analyses we will use a

[7]Note that for reasons of convenient reading we will drop the t index completely in the remainder of the paper.

[8]The hsz measure indeed can be below 0, however, in our sample this rarely is the case. Therefore we will proceed with the assumption as stated and winsorize the few cases with a negative haircut.

loglog-function for this transformation. A more detailed explanation of the beta-regression methodology can be found in Appendix B.

3.3 Variables measuring the ability to repay

To capture the different sources of risk and test our hypotheses we make use of several country specific macro variables as proxies for the risk dimensions. We measure the sovereign's ability to repay by his external debt/GNI ratio (e.debt/GNI) as well as the debt service/GNI ratio (d.serv/GNI). The former can be interpreted as external leverage of the country, whereas the latter gives information about how well the sovereign can handle this leverage. By including the d.serv/GNI ratio we consider that countries do have differences in production technology and overall efficiency, and thereby also vary by the ability to handle a certain leverage. The higher the value of this ratio the better the creditors assess the debt handling capability of the debtor.

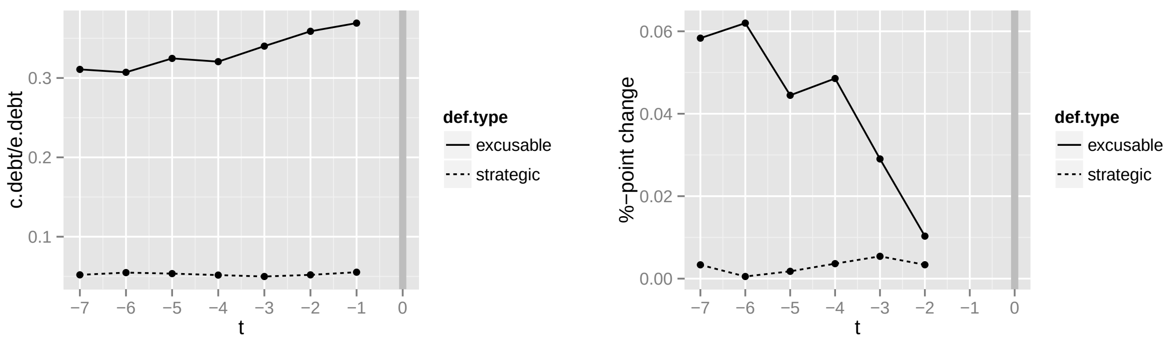
3.4 Variables measuring the willingness to repay

We examine the sovereign's willingness to repay by looking at the relationship between the exposure to possible punishments and the haircut sizes. First, we follow the idea by Gennaioli et al. (2014) who show that the better the development of financial institutions within a country, the severer spillover effects from a sovereign default towards the domestic financial sector. Hence, following their suggestion we use the creditor rights score (c.r.score) by La Porta et al. (1998) to measure the degree of development of financial institutions within a country and take this as one proxy for the severity of the spillover effects. Second, we look at the GNI growth (GNI.growth) of the country within the year ahead of restructuring ($t = -2$ to $t = -1$), in order to measure the short-term economic development. The better this development the less extensive the country seeks for new external debt, and consequently, the market restriction punishment mechanism looses in strength.[9]

3.5 Type of default

As stated by Hypothesis 3, we expect the severity of the punishment mechanisms to influence haircuts differently based on the motivation of default. Debtors defaulting for excusable reasons should be less affected by the severity of the punishment mechanisms while strategic defaulters should be strongly affected. To distinguish the excusable from the strategic default, it is essential to have a proxy which enables to judge whether the default was rather due to the debtor's inability to service outstanding obligations (excusable defaults) or rather due to his unwillingness (strategic defaults) to do so. As it might be beneficial for a debtor to signal inability to strengthen his position towards the following negotiations, the proxy should be manipulation-proof by the defaulting entity. As discussed in Section 2, we think that excusable defaulters can be characterized by having broader access to the concessional debt market. Therefore, we claim that the concessional debt/external debt ratio (c.debt/e.debt) is such a proxy and that debtors drawing relatively high amounts of concessional debt during default episodes can be associated with excusable defaulters, whereas debtors accessing low levels of this sort of debt are strategic ones. According to those arguments, we would expect the c.debt/e.debt ratio for the rather excusable defaulters to notably increase during the negotiation period, and would expect the ratio for the rather strategic ones to show no significant variation. To examine if this is indeed observable in the data in a first step we divide our sample by looking at the c.debt/e.debt ratio at $t = -1$ into two equally sized cohorts. The sovereigns with c.debt/e.debt > 0.21 we assign to the, by our interpretation, excusable cohort, the ones with c.debt/e.debt < 0.21 are assigned to the strategic cohort. We cannot be sure that countries are already in default at all points in time

[9] Benjamin and Wright (2009) also discuss the influence of short-term economic development in their general equilibrium approach, although they focus on the timing of the restructuring. They argue that agreements are more likely in times of economic improvement for the debtor, because thereby his future creditworthiness increases making a nominal exchange offer by the debtor ceteris paribus more attractive to the creditor.



(a) Median c.debt/e.debt ratio.

(b) Difference of c.debt/e.debt median in percentage points relative to the value of the median ratio in t=-1

Figure 2: c.debt/e.debt ratio in the years preceding restructuring. The sample is split in equal sizes by distinguishing type of default according to: c.debt/e.debt < 0.21 representing the strategic cohort, c.debt/e.debt > 0.21 representing the excusable cohort. Panel (a) shows the median c.debt/e.debt of the two cohorts. Panel (b) has the percentage points difference of the c.debt/e.debt at the respective time relative to the value of the median ratio in t=-1.

ahead of restructuring, but Benjamin and Wright (2009) report an average length of default of 7.4 years and Pitchford and Wright (2012) calculate 6.5 years for the average default length. We can therefore expect a considerable number of entities to be in default already at $t = -7$ and the portion increases towards the restructuring. Accordingly, values closer to that date are more expressive. Panel (a) of Figure 2 shows the evolution of the median of the c.debt/e.debt ratio within both cohorts. The first thing to note is that the levels of the ratio for both cohorts differ considerably. As the median for the excusable cohort is above 0.3 for the entire pre-restructuring period, the median for the strategic cohort stays at about 0.05 during the same time. Panel (b) illustrates the difference of the percentage point change of the ratio for a given year relative to the year $t = -1$ ($\frac{c.debt}{e.deb}_{-1} - \frac{c.debt}{e.deb}_{t}, \forall t = -7, ..., -2$) again for the median of both cohorts respectively. Note that referring to the $t = -7$ value, the median of the excusable cohort increased by about 6 percentage points with an upwards trend for most of the time intervals within the observation period. The increase of the median of the strategic cohort within the same period lies just below 0.5 percentage points. This evolution during the restructuring period is well in line with our expectations.

According to our economic arguments not the level but the relative change in the ratio during the negotiation period should be the variable of interest to distinguish type of default. However, it is often difficult to elaborate when the actual default started for a specific entity[10] and therefore this change in the ratio is hard to estimate. On top of that, we think that excusable defaulters tend to have broader access to concessional debt markets ahead of an actual default if third parties judge a future default to be likely. Hence, we claim that the level of the c.debt/e.debt ratio is more suitable to distinguish excusable from strategic defaults and henceforth we use it as a proxy for the type of default in the following analyses.

3.6 Controls

To control for any effects attributed to global business cycle movements we add the US 10-year treasury yield (10y.treasury) as right-hand side variable in all our analyses.[11] As the d.serv/GNI also includes domestic currency debt we additionally consider the defaulting country's inflation to control for effects that are simply artefacts of monetarian policy and have nothing to do with the source of the risk.

To get a technically convenient dataset for our empirical analysis we start out by taking the 180 restructuring of the Cruces and Trebesch (2013) dataset and check for availability of all the explanatory variables at the end of the year ahead of the respective restructuring. We obtain a complete dataset of 108 restructurings. Since we do not want our analysis to be biased by extreme outliers, we winsorize the dataset in each dimension which results in another dropping of six cases leading to a final sample size of 102. A case by case listing of the hsz and the corresponding restructuring dates is given in Table A2. The summary statistics of this final dataset regarding all variables used in the following analyses are shown in Table A3. We use this dataset in each of the following analyses.

[10]In a large number of cases there is no actual default but simply a pre-default restructuring which is usually anticipated and announced long before it is implemented.

[11]See e.g. Cruces and Trebesch (2013) and Hilscher and Nosbusch (2010) who use the variable in a similar context.

4 Empirical analyses

Building on the arguments outlined in Section 2, we now test whether there is empirical support for our three hypotheses within the data. We start by looking at the debtor's ability to repay, then analyze the willingness dimension by looking at the severity of punishment mechanisms, and finally elaborate on the type of default. In the last part of the section we examine the economic relevance of the ability and willingness dimension regarding the recovery risk.

4.1 Debtor's ability to repay

To test Hypotheses 1 and assess whether and by which extend the debtor's ability to repay influences haircuts we apply the following beta-model:

$$\begin{aligned} g(\mu_i) \overset{!}{=} & \ \beta_{constant} + \beta_{e.Debt} \cdot \frac{e.debt}{GNI}_i + \beta_{d.Serv} \cdot \frac{d.serv}{GNI}_i \\ & + \beta_{inflation} \cdot inflation_i + \beta_{10y.treasury} \cdot 10y.treasury_i. \end{aligned} \quad (2)$$

All right-hand side variables are taken at $t = -1$ relative to restructuring. Estimation results of the model are shown in column (1) of Table 1. As expected, the $\beta_{e.Debt}$ is positive at the 1% level, yielding a higher expected haircut for higher external debt leverage. The $\beta_{d.Serv}$ is negative at the 1% level. This implies that the higher the portion of the GNI the country spends to service outstanding debt in the year ahead of restructuring the lower the haircut, which is in line with our assumption about different debt handling capabilities in the cross-section. The $\beta_{10y.treasury}$ is negative at the 1% level yielding that in states of global economic upturn (high 10y.treasury) haircuts are rather low, whereas when the global economy declines (low 10y.treasury) haircuts are high. Inflation is insignificant. Overall, the outcome of this beta-regression supports our Hypothesis 1, by showing that the proxies for the ability to repay debt are indeed related to the size of the haircut.

Table 1: Estimation results of the beta-regressions. Columns (1)-(6) represent the estimation results from the different beta-regression model specifications. Results in column (1), (2), (5), and (6) are obtained by estimating the respective model based on the full sample of the restructurings. Columns (3) and (4) are obtained estimating the models based on restructurings belonging to either the excusable or the strategic cohort. We define cohorts by median splitting the sample referring to the e.debt/c.debt ratio at the year ahead of the respective restructuring (small ratio strat. cohort, large ratio exc. cohort). Significances are calculated applying Wald tests, the labeling is according to: $^{*}p<0.05$; $^{**}p<0.01$. Standard errors of the fitted coefficients are in parenthesis.

	Dependent variable: hsz					
	(1)	(2)	(3)	(4)	(5)	(6)
link-function	loglog	loglog	loglog	loglog	loglog	logit
e.debt/GNI	1.371**	1.381**	1.263**	1.283**	1.128**	1.698**
	(0.186)	(0.178)	(0.322)	(0.235)	(0.179)	(0.264)
d.serv/GNI	−10.410**	−11.201**	−12.470**	−9.576**	−8.247**	−13.417***
	(1.937)	(1.894)	(3.215)	(2.442)	(1.941)	(3.122)
GNI.growth		2.359*	2.024	2.295*		
		(1.027)	(2.462)	(0.942)		
c.r.score		−0.113**	0.030	−0.141**		
		(0.041)	(0.089)	(0.043)		
c.debt/e.debt					1.162**	1.618**
					(0.318)	(0.471)
GNI.growth.m					2.042*	3.745*
					(1.029)	(1.721)
c.r.score.m					−0.104*	−0.181*
					(0.044)	(0.080)
inflation	−0.010	−0.019	−0.243	−0.007	0.003	0.001
	(0.024)	(0.023)	(0.336)	(0.020)	(0.023)	(0.038)
10y.treasury	−0.065**	−0.053*	−0.066	−0.059*	−0.047*	−0.075*
	(0.021)	(0.021)	(0.035)	(0.024)	(0.020)	(0.033)
constant	0.255	0.297	0.577	0.200	−0.046	−0.564
	(0.228)	(0.231)	(0.413)	(0.250)	(0.236)	(0.389)
cohort	all	all	exc.	strat.	all	all
observations	102	102	51	51	102	102
R^2	0.523	0.588	0.557	0.533	0.658	0.645

4.2 Severity of punishment

To examine the relationship between the exposure to possible punishments due to default and the haircut sizes we extend the model to include two variables capturing the willingness dimension: The c.r.score, indicating development of domestic financial institutions, and the GNI.growth, giving an indication for short-term economic development. To elaborate whether Hypothesis 2 is backed by empirical observations, we estimate the following model:

$$\begin{aligned} g(\mu_i) \overset{!}{=} \; & \beta_{constant} + \beta_{e.Debt} \cdot \frac{e.debt}{GNI}_i + \beta_{d.Serv} \cdot \frac{d.serv}{GNI}_i \\ & + \beta_{c.r.score} \cdot c.r.score_i + \beta_{GNI.growth} \cdot GNI.growth_i \\ & + \beta_{inflation} \cdot inflation_i + \beta_{10y.treasury} \cdot 10y.treasury_i. \end{aligned} \tag{3}$$

Estimation results are shown in column (2) of Table 1. We obtain significance for both the GNI.growth and the c.r.score variables. The $\beta_{GNI.growth}$ is positive which indicates higher haircuts for higher pre-restructuring short-term economic growth. This is in line with our intuition stated in Section 3 that the market restriction mechanism weakens as the sovereign's short-term economic situation improves. The $\beta_{c.r.score}$ is negative, yielding a lower haircut for better developed financial institutions which supports our assumption expecting stronger spillover effects for countries with higher leveraged financial institutions. Also note that by introducing the willingness proxies, the coefficient estimates for the yet incorporated ability variables as well as for the controls alter only slightly. This indicates that combined with the ability variables, the willingness proxies provide mainly orthogonal explanation power regarding the haircuts.

4.3 Type of default

Using the c.debt/e.debt as proxy, we examine whether the type of default has a moderating effect on the relationship between the severity of punishment and haircut sizes. To test for this, we first perform a split-sample analysis. Therefore, we maintain cohorts according to median split referring to the c.debt/e.debt ratio as explained in Section 3 and apply the beta-regression-model from Equation (3) to both groups separately.[12]

Estimation results for the excusable cohort are listed in column (3), the results for the strategic cohort in column (4) of Table 1. Significances for the βs of the willingness dimension's proxies, GNI.growth and c.r.score, vanish completely within the excusable cohort. For the strategic cohort we obtain a significant positive $\beta_{GNI.growth}$ estimate at the 5% level and a negative $\beta_{c.r.score}$ at the 1% level. Thus, the β estimates of the two proxies for the severity of the punishment mechanisms support our hypothesis: Within the strategic cohort the severity of the punishment mechanisms measured by these proxies shows a significant relationship with the size of the haircut in the direction we expected. Contrary, in the group of rather excusable defaulters the link of these measures and the haircut is insignificant.

To incorporate the two severity proxies in a full sample model we apply the following moderation, thereby introducing (1-c.debt/e.debt) as a moderator variable:

$$\mathrm{x.m}_i = (1 - \frac{c.debt}{e.debt}_i) \cdot \mathrm{x}_i, \tag{4}$$

where x stands for either one of the two willingness proxies. By this moderation we account for the decreasing influence of the severity variables for excusable defaulters. To capture changes in the absolute level of the c.debt/e.debt ratio we also include the value of the ratio itself, which is common in moderator analysis. From an economic point of view this is also motivated by the fact that so far, in our empirical specification, we neither can incorporate all types of punishment mechanisms nor are we able to consider any effects that might be due to a possible benevolent behavior of the creditors within the negotiations. Such a form of development aid could be especially relevant in case of an excusable default. Using the weighted proxies instead of the original ones and also including the c.debt/e.debt variable,

[12]Summary statistic of the variables involved for both cohorts can be found in Table A3, Panel (b) and (c).

we apply the following model to the full sample:

$$\begin{aligned} g(\mu_i) &\overset{!}{=} \beta_{constant} + \beta_{e.Debt} \cdot \frac{e.debt}{GNI}_i + \beta_{d.Serv} \cdot \frac{d.serv}{GNI}_i + \beta_{c.debt} \cdot \frac{c.debt}{e.debt}_i \\ &+\beta_{c.r.score.m} \cdot c.r.score.m_i + \beta_{GNI.growth.m} \cdot GNI.growth.m_i \\ &+\beta_{inflation} \cdot inflation_i + \beta_{10y.treasury} \cdot 10y.treasury_i. \end{aligned} \tag{5}$$

Results are shown in column (5) of Table 1. The signs of the βs are as expected. The βs for the weighted variables are significant at the 5% level supporting our moderator assumption regrading the c.debt/e.debt ratio. We additionally observe a positive $\beta_{c.debt/e.debt}$ yielding that the variable either accounts for time-series influences which we haven't controlled for yet, or it captures influences of punishment mechanisms which we haven't found proxies for so far. We obtain a pseudo-R^2 of 0.66, which indicates a decent fit of the entire model. We also examine the estimation of the model from Equation (5) using the logit link-function in column (6) of Table 1 and observe similar results. Due to the better pseudo-R^2 of the loglog model, we hold on to this one (column (5)) as the benchmark for further investigations.

Taken as a whole, the evidence suggests a link between the severity of the punishment and the haircut (Hypothesis 2) and is consistent with the type of default hypothesized to have a moderating effect on this relation (Hypothesis 3).

4.4 Economic relevance

Beyond the statistical significance, it is interesting to consider the economic significance of our driving factors. To get a perspective on the magnitude of their effect, we compute the effect of a ceteris paribus change in each of the independent variables on the model-inherent haircut. Table 2 reports the change of our estimated model prediction for the expected haircut ($\Delta\mu$) that arises if we apply ceteris paribus upward shocks of one standard deviation on the respective independent variable. Because of the non-linear transformation by the function g the predicted haircut change $\Delta\mu$ depends on the current level of the

Table 2: Effects on model hsz of ceteris paribus one standard deviation shocks in the respective independent variable. The $\Delta\mu$ respectively equals to the difference between the cohort's median model hsz (median μ) and the model hsz if the variable under investigation is upward shocked by one sample standard deviation.

	(1)	(2)	(3)
variable		$\Delta\mu$	
e.debt/GNI	0.16	0.19	0.29
d.serv/GNI	-0.10	-0.20	-0.19
GNI.growth	-	0.05	0.09
c.r.score	-	0.01	-0.14
c.debt/e.debt	0.09	-	-
GNI.growth.m	0.03	-	-
c.r.score.m	-0.04	-	-
cohort	all	exc.	strat.
median μ	0.38	0.51	0.28
sample size	102	51	51

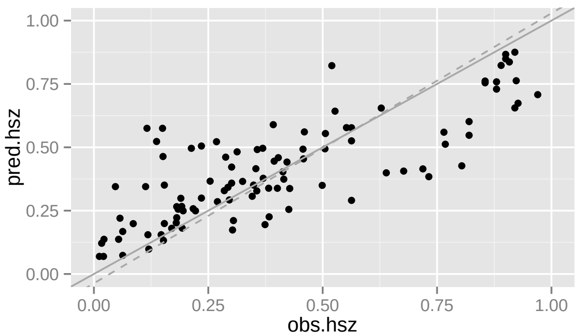
predicted haircut μ. To facilitate comparison, the reported values in Table 2 result from an examination at the median haircut prediction of the respective cohort under investigation. Column (1) corresponds to the full cohort (referring to the model from column (5) of Table 1). In Columns (2) and (3), we split into the excusable and the strategic cohort respectively (referring to the models from column (3) and (4) of Table 1). Let's start with the results for the full cohort. The first item to note is that for the drivers capturing the ability dimension the economic significance is striking in that a one standard deviation shock to external leverage of the country results in a 16 percentage points increase in the haircut and a corresponding shock to the ability to handle leverage changes the haircut by 10 percentage points. The willingness dimension turns out to be economically relevant as well. A one standard deviation shock to the proxy for the degree of creditor rights development leads to a haircut change of 4 percentage points, the shock to short-term economic situation results in a 3 percentage points shift of the haircut estimate.

Looking at column (2) and (3) it is interesting to examine the cross-variation of the $\Delta\mu$'s over the two cohorts, to compare the importance of the ability and the willingness dimension amongst them. From our analysis so far, we would ex ante expect a very similar behavior across both samples for the ability dimension while we expect a shock with respect to the willingness dimension to have a stronger effect within the strategic cohort. Indeed, once we go from the excusable to the strategic cohort the impact on the haircut almost doubles due to a shock to the short-term economic situation and the difference becomes even more evident for a shock to our spillover proxy. Thus, both willingness proxies clearly lead to economically stronger effects for strategic defaulters. Regarding the ability dimension, the $\Delta\mu$ of the strategic cohort due to a one standard deviation shock to the external leverage is about 1.5 times the value of the excusable cohort, whereas there is almost no cross variation of the $\Delta\mu$'s that approximate the leverage handling ability. The latter result is in line with our expectations; the increased sensitivity due to a shock in the external leverage - though being clearly lower than for the willingness proxies - is somewhat puzzling, however. One possible explanation is that our external leverage proxy for ability captures also part of a willingness component. Basu (2009) points in this direction as he theoretically shows that a higher amount of external debt relative to that held domestically leads to higher haircut decisions in equilibrium if the sovereign cannot discriminate between external and internal debtors. His results are due the fact that haircuts on domestic debt impose high spillover effects as a result of the weakening of the domestic economy within his model. If we would assume that external debt per GNI is positively correlated with external debt per internal debt and the nondiscrimination assumption of Basu (2009) holds, our external leverage proxy for ability should also incorporate a willingness component.[13]

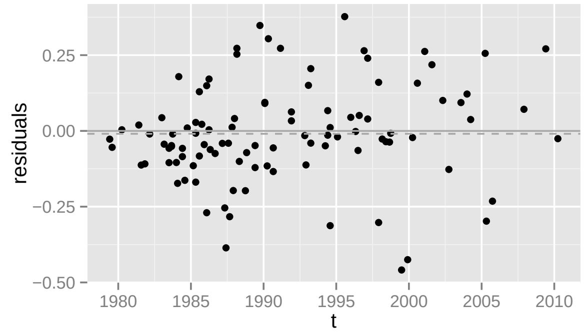
5 Forecasting haircuts

So far we have relied on the pseudo-R^2 to judge the goodness of fit of the respective models. However, interpretation of this ratio is not straight forward. Thus, to enable better interpretation and to develop a benchmark for our out-of-sample tests which we perform

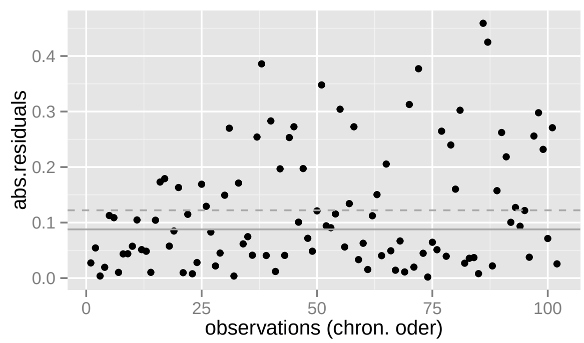
[13]Due to inflation issues it is hard to value internal debt as well as to measure haircuts on internal debt, which is why our empirical study purely focuses on external debt.



(a) Observed vs. predicted hsz.



(b) Residuals of prediction in chron. order.



(c) Absolute residuals of prediction.

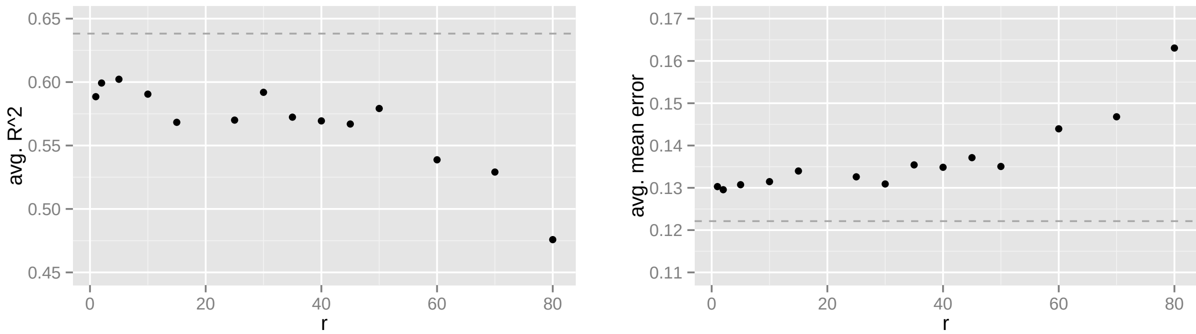
Figure 3: Examination of in-sample goodness of fit for the benchmark model. Panel (a) shows the observed vs. the model *hsz*. The solid line is the 45°-diagonal the dashed line is the linear regression fit. Panel (b) shows the residuals of the benchmark model estimation in chronological order. Panel (c) has the absolute residuals. The solid and the dashed line represent median and mean respectively in Panel (b) and (c).

subsequently, we examine the in-sample fit of the model first. Figure 3 shows three plots referring to the differences between observed and predicted values. The predicted values of the *hsz* correspond to the estimation of the full model (see column (5) of Table 1).

Panel (a) illustrates the observed vs. the predicted *hsz*s. The solid line is the 45°-diagonal, the dashed line represents the fitted linear regression line. Apparently, the model does not perfectly match our data, but slightly over-predicts values within the lower tail of the distribution while under-predicting values within the upper tail. However, we still obtain a decent overall fit with a squared correlation coefficient of 0.64, yielding that 64% of the variance in the observed data is explained by the model. This is well in line with Acharya et al. (2007) who reach a R^2 of 0.68 within a similar study for corporate recovery rates. Residuals in chronological oder are shown in Panel (b). Their distribution is almost symmetric around zero (the dashed line representing the mean at -0.01) with no observable pattern along the time series providing further backing for the model. Panel (c) illustrates the absolutes values of the residuals including their median (solid line) and mean (dashed line). We obtain an average prediction error of 0.12 implying that our model-predictions are on average 12 percentage points off. The median is at 0.09 indicating that for at least half of the cases the error is below 9 percentage points. Based on this in-sample goodness of fit measures as a benchmark, we will now asses the ability of our model to forecast haircut sizes conditional on the restructuring taking place within the year ahead. Since sovereign defaults are rare, the sample size is small already. Performing out-of-sample (OOS) tests even leads to further reduction of this size. Hence, for preparing the forecasting analysis we initially perform OOS tests to determine a critical sample size for which the estimation still shows persistent results. We start by randomly picking e (for exclusion) restructurings and exclude them from the sample.[14] Then we estimate the full model according to Equation (5) with the remaining data and predict the haircuts for the excluded restructuring cases. We rerun this procedure $l = \frac{\lfloor \text{sample Size} \rfloor}{e}$ times[15], receiving a sample of $e \cdot l$ (estimated hsz/original hsz) pairs. To smooth out specific sampling effects, we loop through these steps 50 times for each e. Following this, we compute the average R^2 between the OOS estimates and the observed values as well as the average absolute value of the residuals. Results are shown in Figure 4. Panel (a) displays the evolution of the average R^2 vs. the increasing number of restructurings we excluded from the total sample, Panel (b) shows the associated average mean absolute residuals. The dashed lines represent the corresponding values from the in-sample evaluation. We observe that up to an exclusion number e of around 50 the model shows persistence, with the performance measures being close to their in-sample counterparts, whereas for $e > 50$

[14]By selecting the excluded cases randomly we seek to determine the minimum critical sample size for which our model shows persistent behaviour. Given our independent variables are stationary the critical sample size shouldn't depend on whether we select the exclusions at random positions or cut of the tail (referring to the time-series dimension) of our sample series.

[15]We do so to obtain OOS sizes within the ballpark of the original sample size.



(a) Average R^2 development.   (b) Average mean abs. residual development.

Figure 4: Panel (a) shows the average *pseudo*-R^2, Panel (b) the average mean absolute residual development of a randomly applied out-of-sample evaluation of the benchmark model. Both paths are constructed by randomly excluding e data points from our original sample to then estimate the benchmark model based on the reduced sample size and forecast the excluded values. We rerun this $l = \frac{\lfloor \text{sample Size} \rfloor}{e}$ times to get a sample size $e \cdot l$ within the ballpark of the original sample size to make the R^2 comparable. For each e we average over 50 loops of theses exclusion-forecasting rounds (each of size $e \cdot l$) to smooth out sampling effects. The dashed line shows the respective in-sample value.

performance clearly decreases.

Motivated by these results, we now evaluate the performance of a rolling forecasting model for the *hsz*. We start by estimating the model on data obtained up to the end of 1990, thereby having an initial sample of 57 restructuring cases (this means we excluded 45 cases). We then forecast the *hsz*s after this date on a rolling basis, i.e. we re-estimate our model repeatedly always including the respective restructuring that occurred before the next forecasting date. This simulates how the model would have performed forecasting haircuts if one would have started using it by the end of 1990. Observed vs. predicted *hsz*s of the OOS-estimations are shown in Figure 5. The solid line (45°-diagonal) and the dashed line (resulting from a simple linear regression of the two variables) are close, indicating a good fit of the overall forecasting model. We obtain an out-of-sample R^2 of 0.52 and an average absolute forecasting error of 16 percentage points, which are both slightly worse but still within the ballpark of the in-sample measures.

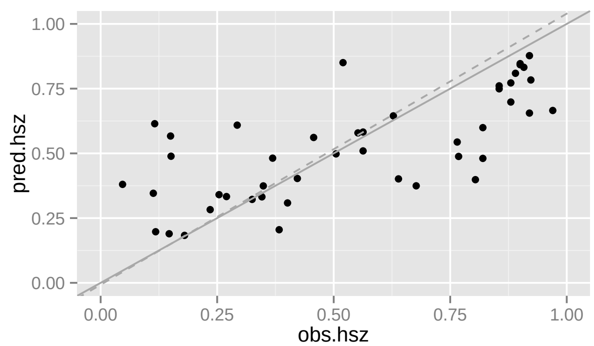


Figure 5: Observed vs. predicted hsz from the forecast starting at the beginning of 1991. Observed values are from Cruces and Trebesch (2013), predicted values are calculated by first estimating the benchmark model using observations that occurred before the respective examination date, and then out-of-sample predicting the next *hsz* using the (mainly countryspecific) values for the independent variable at the time.

6 Conclusion

Based on the hypotheses we developed in Section 2, we examine the relationship between several potential driver and the sizes of sovereign haircuts. We do so by estimating beta-regression-models linking haircuts from our sample of 102 past restructurings to proxies of possible drivers for the haircut. The results show that the sizes of the haircuts are linked to the ability of a debtor to service future obligations measured by the proxies e.debt/GNI and d.serv/GNI. Also the debtor's exposure to possible impacts from potential punishment due to default is related to the haircuts in our data. Further, we provide support that the link of this exposure and the haircuts depends on the type of the defaulter measured by the c.debt/e.debt ratio. We also provide arguments that support the usage of the c.debt/e.debt ratio as a proxy for the type of the default. Finally, we use the results from our analyses to forecast the size of 45 haircuts from restructurings which took place in the period from 1991 to present, always conditional on the restructurings being one year ahead, and reach a R^2 of 0.52.

Our hypotheses focus on the differences in fundamental characteristics of sovereigns which are mainly linked to future cash-flows to the bond holders. Since we mix time-series with cross-section analyses variation in risk aversion could be a major factor being incorporated by our proxies, too. To check by which extend the observed relationships can be attributed to the cash-flow level it would be interesting to include our approach in an asset-pricing context using market prices of credit-risk products, e.g. sovereign credit default swaps or bonds, thereby also enlarging the sample size to then investigate whether the linkages we observe maintain within analyses of long-horizon returns that also regard variables which yield variation in the risk aversion.

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Appendix

A Data

Table A1: The table describes all variables we use within our empirical analysis. The first column holds the full name of the variable followed by our abbreviation in the second column. The third column gives a detailed explanation of the respective variable, in column four we list the data source.

Data description			
Variable	Abbreviation	Description	Source
Haircut by Sturzenegger and Zettelmeyer (2005)	hsz	Haircuts are calculated by discounting both old and new debt with the (default) exit yield as explained in Section 3.	Cruces and Trebesch (2013)
Total external debt stocks per GNI	e.debt/GNI	Total external debt is debt owed to nonresidents repayable in currency, goods, or services. It is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Short-term debt includes all debt having an original maturity of one year or less and interest in arrears on long-term debt. GNI (formerly GNP) is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad.	World Bank
Total debt service per GNI	d.serv/GNI	Total debt service is the sum of principal repayments and interest actually paid in currency, goods, or services on long-term debt, interest paid on short-term debt, and repayments (repurchases and charges) to the IMF	World Bank
GNI growth	GNI.growth	Percentage growth of the GNI within the year ahead of the restructuring (from t=-2 to t=-1).	World Bank
Creditor rights score	c.r.score	Developed by La Porta et al. (1998) it is the leading institutional predictor of credit market development around the world. Measures the availability and enforecement of creditor rights within a country.	Djankov et al. (2007)
Concessional debt per total external debt stocks	c.debt/e.debt	Concessional debt is defined as loans with an original grant element of 25 % or more.	World Bank
inflation	inflation	Inflation as measured by the consumer price index. It reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals within the year ahead of restructuring (from t=-2 to t=-1). The Laspeyres formula is generally used.	World Bank
10-year US treasury yield	10y.treasury	The yield of 10-year US treasury bonds.	Recent quotes back to 1990 from US Dep. of the Treasury, quotes before 1990 from Shiller (2000).

Table A2: End-of-restructuring dates and hsz of our final dataset in chronological order. The data is from Cruces and Trebesch (2013).

#	Restr.	Debtor	hsz
1	06/1979	Turkey	0.22
2	08/1979	Turkey	0.20
3	04/1980	Congo	0.30
4	06/1981	Jamaica	0.15
5	08/1981	Turkey	0.09
6	11/1981	Madagascar	0.19
7	03/1982	Turkey	0.17
8	01/1983	Congo	0.38
9	03/1983	Malawi	0.28
10	07/1983	Nigeria	0.01
11	07/1983	Peru	0.06
12	09/1983	Costa Rica	0.39
13	09/1983	Nigeria	0.02
14	10/1983	Ecuador	0.06
15	01/1984	Brazil	0.02
16	02/1984	Senegal	0.29
17	03/1984	Niger	0.37
18	06/1984	Congo	0.30
19	06/1984	Jamaica	0.18
20	08/1984	Ecuador	0.06
21	10/1984	Madagascar	0.41
22	03/1985	Mexico	0.02
23	05/1985	Congo	0.37
24	05/1985	Costa Rica	0.36
25	05/1985	Senegal	0.31
26	08/1985	Argentina	0.30
27	08/1985	Mexico	0.05
28	10/1985	Panama	0.12
29	12/1985	Ecuador	0.15
30	02/1986	Dom. Rep.	0.50
31	02/1986	Morocco	0.23
32	04/1986	Niger	0.46
33	04/1986	Philippines	0.43
34	05/1986	Congo	0.35
35	09/1986	Brazil	0.19
36	03/1987	Mexico	0.18
37	05/1987	Congo	0.27
38	06/1987	Madagascar	0.14
39	08/1987	Argentina	0.22
40	09/1987	Morocco	0.21
41	11/1987	Nigeria	0.19
42	12/1987	Philippines	0.15
43	01/1988	Nigeria	0.41
44	03/1988	Bolivia	0.93
45	03/1988	Mexico	0.56
46	05/1988	Togo	0.46
47	10/1988	Malawi	0.39
48	11/1988	Brazil	0.18
49	06/1989	Congo	0.51
50	06/1989	Nigeria	0.30
51	10/1989	Honduras	0.73
52	02/1990	Mexico	0.30
53	02/1990	Philippines	0.43
54	04/1990	Madagascar	0.53
55	05/1990	Costa Rica	0.72
56	09/1990	Morocco	0.40
57	09/1990	Senegal	0.36
58	03/1991	Niger	0.82
59	12/1991	Mozambique	0.90
60	12/1991	Nigeria	0.40
61	11/1992	Brazil	0.27
62	12/1992	Philippines	0.25
63	02/1993	Uganda	0.88
64	04/1993	Argentina	0.32
65	04/1993	Bolivia	0.76
66	04/1994	Brazil	0.29
67	06/1994	Bulgaria	0.56
68	06/1994	Zambia	0.89
69	08/1994	Dom. Rep.	0.50
70	08/1994	Panama	0.15
71	02/1995	Ecuador	0.42
72	08/1995	Albania	0.80
73	01/1996	Ethiopia	0.92
74	05/1996	Panama	0.35
75	07/1996	Algeria	0.23
76	08/1996	Mauritania	0.90
77	12/1996	Senegal	0.92
78	03/1997	Macedonia	0.35
79	03/1997	Peru	0.64
80	12/1997	Togo	0.92
81	12/1997	Vietnam	0.52
82	03/1998	Cote d'Ivoire	0.63
83	06/1998	Kenya	0.46
84	09/1998	Ukraine	0.12
85	10/1998	Ukraine	0.15
86	07/1999	Pakistan	0.12
87	12/1999	Pakistan	0.15
88	04/2000	Ukraine	0.18
89	08/2000	Ecuador	0.38
90	02/2001	Rep. of Yemen	0.97
91	08/2001	Honduras	0.82
92	05/2002	Cameroon	0.85
93	10/2002	Moldova	0.37
94	08/2003	Cameroon	0.85
95	01/2004	Tanzania	0.88
96	04/2004	Moldova	0.56
97	04/2005	Argentina	0.77
98	05/2005	Dom. Rep.	0.05
99	10/2005	Dom. Rep	0.11
100	12/2007	Rep. Congo	0.91
101	06/2009	Ecuador	0.68
102	04/2010	Cote d'Ivoire	0.55

Table A3: Summary statistics of variables involved in the empirical analysis. Panel (a) covers the full sample, Panel (b) and (c) show the values for the two subsamples resulting from a median split regarding the c.debt/e.debt ratio in the year ahead of the respective restructuring (small ratio strat. cohort, large ratio exc. cohort).

Panel (a): Full sample (102 restructurings)				
Variable	Mean	St. Dev.	Min	Max
hsz	0.403	0.271	0.012	0.970
e.debt/GNI	0.787	0.400	0.225	2.146
d.serv/GNI	0.062	0.033	0.008	0.126
c.debt/e.debt	0.248	0.214	0.005	0.846
GNI.growth	0.027	0.053	−0.135	0.158
c.r.score	1.451	1.216	0	4
inflation	0.604	2.043	−0.025	19.280
10y.treasury	8.010	2.539	2.520	14.500
Panel (b): (Rather) excusable cohort (51 restructurings)				
Variable	Mean	St. Dev.	Min	Max
hsz	0.519	0.280	0.116	0.970
e.debt/GNI	0.914	0.398	0.276	2.146
d.serv/GNI	0.061	0.032	0.008	0.120
c.debt/e.debt	0.417	0.171	0.212	0.846
GNI.growth	0.033	0.039	−0.057	0.113
c.r.score	1.333	0.973	0	4
inflation	0.196	0.294	−0.025	1.833
10y.treasury	7.941	2.637	3.730	14.500
Panel (c): (Rather) strategic cohort (51 restructurings)				
Variable	Mean	St. Dev.	Min	Max
hsz	0.288	0.207	0.012	0.804
e.debt/GNI	0.661	0.364	0.225	1.710
d.serv/GNI	0.064	0.035	0.009	0.126
c.debt/e.debt	0.079	0.070	0.005	0.210
GNI.growth	0.021	0.063	−0.135	0.158
c.r.score	1.569	1.418	0	4
inflation	1.012	2.829	0.005	19.280
10y.treasury	8.079	2.461	2.520	12.500

B Beta-regression basics

The beta-regression methodology by Cribari-Neto and Ferrari (2004) is based upon the assumption that the dependent variable y, in our case being the haircut, is beta-distributed. This is a minor restrictive assumption, since the density function of the beta distribution can adopt a broad variety of shapes within the $(0,1)$ interval. The density function of the distribution is

$$f(y,\mu,\phi) = \frac{\Gamma(\phi)}{\Gamma(\mu\phi)\Gamma((1-\mu)\phi)} y^{\mu\phi-1}(1-y)^{(1-\mu)\phi-1}, \quad 0 < y < 1, \tag{B1}$$

with $0 < \mu < 1$, $\phi > 0$, and $\Gamma(\cdot)$ labeling the Gamma-function. Using this parametrization the moments of the distribution are

$$E(y) = \mu \qquad \text{and} \qquad Var(y) = \frac{\mu(1-\mu)}{1+\phi}.$$

As obvious from the variance definition, a beta-regression model naturally allows for heteroscedasticity. Assuming that y_i for $i, 1, .., n$ are independent realizations of random variables according to the distribution characterized by Equation (B1) with means μ_i, using a strictly monotone twice differentiable function $g(\cdot)$, which maps the $(0,1)$ interval into $\mathbb{R}$, the transformation of the independent variable observations is linked to data as:

$$g(\mu_i) \stackrel{!}{=} \sum_{j=0}^{k} x_{ij} \cdot \beta_j = x' \cdot \beta. \tag{B2}$$

$g(\cdot)$ is referred to as *link-function*, since it links the dependent variable with the regressors. ϵ_i is an error term that needs no further specification. Within our analyses we make use of either one of the following link functions:

$$\text{log-log: } g(y_i) = -log(-log(y_i)) \tag{B3}$$

$$\text{logit: } g(y_i) = log(\frac{y_i}{1-y_i}) \tag{B4}$$

The variables x_{ij} for $j = 1, .., k$ hold the values of the independent variables, $x_{i0} = 1$ representing the constant. The corresponding β_j for $j = 0, .., k$ are the coefficients we seek to fit to investigate the influence of the regressors on the haircut. The model is calibrate by applying maximum-likelihood estimation based on the log-likelihood function

$$\begin{aligned} l(\beta, \phi) = \sum_{i=1}^{n} l(\mu_i, \phi) &= \sum_{i=1}^{n} log(\Gamma(\phi)) - log(\Gamma(\mu_i)\phi) - log(\Gamma((1-\mu_i), \phi)) \\ &+(\mu_i\phi - 1)log(y_i) + [(1-\mu_i)\phi - 1]log(1-y_i), \end{aligned} \tag{B5}$$

with μ_i so that Equation (B2) holds. To asses the fit of the model a *pseudo* R^2 which compares the likelihood of the fitted model with the theoretical maximum likelihood is calculated. The influence of the regressors is tested by applying Wald tests. For are more detailed explanation of the pseudo-R^2 and the Wald test see Cribari-Neto and Ferrari (2004).