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Use and limits in project finance of the capital asset pricing model: overview of highway projects

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The Capital Asset Pricing Model (CAPM) has become the standard and most popular tool in corporate finance for assessing the risk and return in a shareholder´s equity. It is widely used in project finance, particularly in transportation projects. Yet in highly leveraged projects, the CAPM can produce misleading results. In this paper, we show that the values that the CAPM provides for projects that use debt to finance more than 80% of their total investment are unrealistic. This finding is mainly the result of a high leverage value in the CAPM formula. We examine 20 highway projects in Portugal launched between 1999 and 2010. We argue that in transport projects with high debt levels, investors must rely on the weighted average cost of capital. We find that larger and more complex projects tend to have higher equity and capital costs. Further, the financial crisis has a significant effect on increasing the cost of these projects.

Keywords: *capital asset pricing model, highways, project finance, public private partnerships, transport,*
JEL Classification: G11; G32; H43; R42

1. Introduction

The Capital Asset Pricing Model (CAPM), as a risk and return model, has become the most popular tool in corporate finance for assessing the cost of capital (in the sense that measures the expected return of an asset and the systematic risk given by the available market assets). The CAPM is based on Markowitz's (1952) Portfolio Theory and the efficient market hypothesis (i.e., market prices react rapidly to new information).

Over the last few decades, governments have developed large infrastructure projects through public private partnerships (PPPs) by using a different financing mechanism called project finance. This is the result of the private sector's commitment to providing public services, and the importance of common objectives being aligned with the public sector to ensure the success of PPP projects (Tsamboulas et al., 2013). European governments have been particularly active in using PPPs, especially in the transport sector (Berechman et al., 2006). A recent study by Roumboutsos (2015) indicates that in 2013, there were more than 1,600 PPPs in Europe, with a

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cumulative investment of €300 billion. Furthermore, 80% of the European Investment Bank's loans made to PPP projects between 1990 and 2014 were for the transportation sector (EPEC, 2015). Worldwide, the transportation sector has captured most of the investment (in terms of number of projects and investment volume) in PPPs; within this sector, highways have been the main object of the projects, as they are the dominant form of transportation for freight and passenger movement throughout the world (Estache et al., 2000). The PPPs and project finance have been the main form of financing and funding for transportation infrastructure.

We can define project finance as "a non-recourse or limited resource financing structure in which debt, equity and credit are enhanced for the construction and operation of a particular facility in a capital-intensive industry" (Yescombe, 2013). Project finance has several characteristics that distinguish it from traditional corporate finance. First, it comes in a certain form: a Special Purpose Vehicle (SPV) (Gatti, 2013). In project finance, a SPV portfolio consists of a single project (Faboozi & de Nahlik, 2012). As referred to by Brealey et al. (1996), the advantage of project finance is to allow the proper allocation of risk to a specific project. Because of debt, project finance is highly leveraged (usually three times more than corporate finance, Esty, 2004) on a "non-recourse" debt with a priority scheme. Despite high leverage of around 80% to 90% (Blanc-Brude & Strange, 2007), until the recent financial crises, interest rates were low (spreads from 1-2%), which was a little above the free-risk rate (Sarmento & Renneboog, 2016). Project finance allows investors to observe the determinants and effect of decisions in a more efficient, transparent way than corporate finance (Esty, 2004).

In project finance, the CAPM has been a crucial way of addressing the cost of the project's capital (Gatti, 2013Yescombe2013). However, both academics and practitioners tend to use it without addressing the differences between project finance and corporate finance. To our knowledge, given the many critics of the CAPM, the literature has never applied the CAPM to project finance or to a highly leveraged firm.

This paper addresses the financing of transportation infrastructure and the effects of specific characteristics in project finance on the use of the CAPM. We use Portuguese highways to achieve two objectives: first, to use the CAPM for each project to measure the effects of investment and leverage. We assess efficiency in the use of the CAPM under highly leveraged finance conditions, which characterizes project finance. Second, to understand how project variables can affect the CAPM.

This paper is organized as follows: Section 2 presents the theoretical background of the CAPM and its limitations. Section 3 presents the Portuguese highway projects. The method and data are presented in Section 4, with results in Section 5. Section 6 concludes.

2. Capital asset pricing model

The CAPM describes the relation between systematic risk in and the expected return of assets by measuring the variance in the returns and risk markers for a well-diversified portfolio. It is widely used for estimating the cost of capital for firms and evaluating the performance of managed portfolios (Fama & French, 2002, 2004). The CAPM was developed independently by Sharpe (1964), Lintner (1965), and Mossin (1966) and has become a cornerstone in finance, particularly in corporate finance and investment valuation. The finance literature on this topic is wide and varied. Industries around the world have come to rely on the CAPM for a range of finance decisions; for example, determining the discount rate for investment valuation of firms, setting sales prices in the regulation of utilities, and benchmarking fund managers, among others (Dempsey, 2013).

The CAPM assumes there are no transaction costs, as all assets are traded and investments are infinitely divisible (this means an investor can buy any fraction of a unit of any asset). There is no asymmetric information, and investors can diversify without additional costs. The CAPM represents the value that investors expect based on a risk-free rate plus a market risk premium, which is multiplied by the investor's exposure to markets.

Despite the number of papers and use of the CAPM to assess the empirical behavior of markets, the method has been subject to some degree of criticism (Dempsey, 2013). Most has come from the assumptions in the model (Merton, 1973). Despite the fact that some authors (Miller & Scholes, 1972; Black, 1972; Fama & McBeth, 1973) demonstrate a clear relation between firms' betas (the beta of an asset represents the risk measure of a specific asset versus the risk of the market. It is obtain by dividing the covariance of the asset with the market portfolio with the variance of the market portfolio. Betas higher than 1 means a asset riskier than the market average) and asset return outcomes, there has been some concern about the ineffectiveness of the betas used to calculate the CAPM.

As stated by Dempsey (2013), the returns on stocks with higher betas are systematically lower than predicted by the CAPM, while those of stocks with lower betas are systematically higher. The average return for an asset over multiple periods is insensitive to its beta. This sensitivity means that markets might not be able to price risk differentially across assets.

Fama and French (1993, 1995, 2004) have developed another approach to the CAPM: the three-factor model. This new model uses three distinct types of risk found in the equity market to support ireturns classification: book and market value, size, and leverage. They use firm specific characteristics, and not just the market factor, to explain the return behavior of different types of portfolios.

However, the CAPM remains, for projects and companies, the most popular as well as a cornerstone in corporate finance and investment valuation. Yet, very few studies have focused on the use of the CAPM in transportation. Kavussanos & Marcoulis (1997) look at the CAPM in US water transportation and find that the systematic risk of the shipping industry return is not different from that of the "average" firm but also to the effect of size in the return. The CAPM in airlines is analyzed by Lai (2009) who calculates the underwriting of systematic risk and profit margins in aviation. To our knowledge, no study has applied the CAPM to highways projects.

3. Portuguese highways

Since 1993, Portugal has been using PPPs extensively, mainly for highway construction and the health sector. Portugal is one of the richest examples of PPP use in transportation infrastructure (Sarmento & Renneboog, 2015). Portugal is the European PPP leader (in large PPPs as a percent of GDP – Sarmento & Renneboog, 2017). The network increased by 700% between 1990 and 2007 and is similar to that in Ireland (+900%), and Greece (+500%) (Cruz & Marques, 2011). From an almost nonexistent highway network in 1986 (less than 100 km), Portugal had more than 4.000 km by 2015 (Macario et al., 2015). Portugal is now among the countries with the highest density (measured by the number of km by million habitants) of highways in Europe that represents more than €18 billion in private investment via PPPs (Sarmento & Renneboog, 2015). A map containing the Portuguese highway network at the current situation is presented in Figure 1.

Figure 1 – Portuguese highway network (2017)
Source: Portuguese government

As one of the leading countries using PPPs, the Portuguese experience is impressive, relevant, and worthy of study because of the large number of projects but also because of their fast pace of development. Yet, since its inception, there has been strong discussion and controversy about it being the best contracting option for highways (and whether these public-private partnerships have, in fact, delivered value for money to the public sector). Portugal's experience in developing a high number of PPPs in a short period of time despite a substantial number of pitfalls and errors (Sarmento & Renneboog, 2015) could serve as a lesson for countries developing infrastructure through schemes like PPPs or concessions.

The government divided the first wave of PPPs for the highway sector into seven separate procedures between 1999 and 2001. These projects (called SCUT- the acronyms in Portuguese for "no cost to user) extend over a total of 930 km of highways and use shadow tolls where the public budget steps in to pay the private fees in lieu of users.

The government launched the second wave of road PPPs between 2007 and 2008, when it awarded seven new highway projects to public bids. The Estradas de Portugal (EP) is a state-owned company that was the concession grantor, which explains why these roads are referred to as "sub-concessions." These projects were completed by 2014 and added €800 million of annual government payments. Sub-concession contracts are similar to the former SCUT contracts: the roads have actual tolls where the revenue reverts to the EP, while the concessionaires receive payments based on availability.

Table 1 presents the main data on PPPs, with Table 2 presenting the financial data. The government launched a total of 22 projects for 4,300 km between 1995 and 2012. This amount represents a total investment of €18.8 billion (in current prices), and is more than 10% of GDP. Debt financed the private investment and totaled €13.7 billion. This is an average leverage of 73%, with most projects having between 70 and 90% in debt. As contracts were over 30 years, the debt was financed with longer maturities, usually over 20 years. Debt maturity was covered in almost all projects, for two-thirds of the contract period.

The availability payment, a fixed rent from the public sector to the private firm, is an important choice for project revenues, only five were based on collecting tolls. There are two main reasons for the decision to pay the private sector with an availability scheme. The first reason is that most highways had insufficient traffic to guarantee a private return rate. The reasons to build these highways were mainly political. The private sector would not have taken on these projects if it had had to bear the demand risk. The second reason is because the private sector received an availability payment, as tolls are a public revenue. This decision was made with the purpose of putting the EP outside state budget by having commercial revenues to pass the market rule in EU public accounting rules (European System of Accounts 2010) that reduced the public deficit and debt (see Sarmento & Renneboog, 2015 for further explanations on this accounting scheme). This decision represents public payments with a net present value, with a 6% discount rate, of around €12.2 billion.

Table 1. Portuguese PPP data

PPP	Year begin	Nº years	Length (Km)	Type of Payment	Nº share-holders	% capital owned by foreign shareholders	% capital owned by		
							Construction groups	Banks	Other share-holders
Lusoponte	1995	30	17	Tolls	9	57	53	0	47
Norte	1999	36	175	Tolls	14	0	80	20	0
Oeste	1999	30	85	Tolls	11	10	80	10	10
Brisa	2000	35	1.099	Tolls	n.a	n.a	n.a	n.a	n.a
Litoral Centro	2004	30	92	Tolls	4	0	0	10	90
Scut da Beira Interior	1999	30	174	Availability	6	20	100	0	0
Scut da Costa de Prata	2000	30	110	Availability	13	0	82.5	17.5	0
Scut do Algarve	2000	30	127	Availability	9	82	100	0	0
Scut Interior Norte	2000	30	155	Availability	5	70	100	0	0
Scut Beira Litoral Alta	2001	30	173	Availability	13	0	82.5	17.5	0
Scut Norte Litoral	2001	30	120	Availability	9	79	100	0	0
Scut Grande Porto	2002	30	56	Availability	12	0	82.5	17.5	0
Grande Lisboa	2007	30	23	Availability	9	0	82.5	17.5	0
Douro Litoral	2007	27	129	Availability	5	0	45	0	55
AE Transmontana	2008	30	29	Availability	7	47	100	0	0
Douro Interior	2008	30	186	Availability	9	0	85	15	0
Tunel do Marão	2008	30	242	Availability	5	0	100	0	0
Baixo Alentejo	2009	30	345	Availability	8	50	100	0	0
Baixo Tejo	2009	30	70	Availability	7	15	25	0	75
Litoral Oeste	2009	30	273	Availability	4	20	0	0	100
Algarve Litoral	2009	30	109	Availability	9	45	100	0	0
Pinhal interior	2010	30	520	Availability	9	0	80	20	0
Total road sector	**----**	**----**	**4.310**	**----**	**----**	**----**	**----**	**----**	**----**

Note: This table presents the main data for the characteristics of highway PPPs in Portugal (year, nº years of concession, km for roads and railways and the types of payment for tolls, availability, or service). It also presents the NPV of public payments (in € millions) based on the PPP contract year and using the 6% legal discount rate. For the PPP shareholders, the table presents the nº shareholders; the percentage of capital owned by foreign shareholders; and the percentages of capital owned by construction groups, banks, or other type of shareholders. Source: own table (organized by the concession year), based on Portuguese Ministry of Finance data

Table 2. PPP financial data

Highways	Year	Capex	Debt %	Debt spreads	Debt maturity	DSCR	Project IRR
Lusoponte	1995	897	50	n.a	21	1.40	11.20
Norte	1999	1,570	60	1.20	28	1.43	8.81
Oeste	1999	415	70	0.50	15	1.25	10.6
Brisa	2000	4,096	58	n.a	n.a	n.a	n.a
Litoral Centro	2004	587	90	1.20	24	1.59	n.a
Scut da Beira Interior	1999	774	97	1.00	20	1.30	7.35
Scut da Costa de Prata	2000	492	81	1.20	25	1.42	8.43
Scut do Algarve	2000	295	79	1.30	23	1.70	9.08
Scut Interior Norte	2000	726	89	1.30	30	1.39	9.59
Scut Beiras Litoral-Alta	2001	1,020	90	1.25	24	1.39	10.45
Scut Norte Litoral	2001	317	49	1.35	25	2.10	8.78
Scut Grande Porto	2002	763	76	1.20	27	1.37	9.33
Grande Lisboa	2007	256	67	1.00	27	1.52	6.39
Douro Litoral	2007	1,200	91	1.10	24	1.23	5.92
AE Transmontana	2008	784	73	1.60	27	1.28	6.71
Douro Interior	2008	800	94	1.50	27	1.20	7.59
Tunel do Marão	2008	940	69	1.00	27	1.37	6.69
Baixo Alentejo	2009	561	70	2.00	27	1.45	7.23
Baixo Tejo	2009	437	78	1.90	28	1.20	15.9
Litoral Oeste	2009	529	95	2.50	28	1.23	7.23
Algarve Litoral	2009	622	27	1.60	21	1.46	8.01
Pinhal interior	2010	1.244	91	2.75	17	1.21	9.81
Total road sector	----	18,801	------	-----	-----	----	----

Note: This table presents financial data for the highway PPPs in Portugal. "n.a" signifies "not available". "Capex" represents the total amount of investment in the project (at current prices). "Total debt" represents the amount of capex finance through debt. "Debt EIB" represents the amount of debt finance by the European Investment Bank. All values are in millions of Euros. Source: own table (organized by the concession year), based on Portuguese Ministry of Finance data

4. Method and data

This paper has two objectives: to use the CAPM in each project to measure the effect of investment and leverage. How efficient and proper is the use of CAPM under the specific finance conditions that characterize project finance? How do project variables (size of the highway, measured by length, type of shareholders (domestic or foreign), availability or toll payments, and effect of the financial crisis) impact the CAPM? For this, we used the Portuguese highway case. From the 22 projects described earlier, we were able to collect data for a total of 20 observations.

To assess our first research question, we calculate the CAPM for each highway project in our sample. The CAPM (designated as r_E , the return on equity) is calculated as follows:

$$r_E = R_f + \beta_L (\bar{R}_M - R_F) \quad (1)$$

where R_f is the risk-free rate, β_L is the levered beta, and $(\bar{R}_M - R_F)$ is the expected market risk premium. For the market premium, we use the Victoria Department of Treasury and Finance's (2003) value of 6% (as this is the only market premium available for PPPs in a matured and developed market) that yields an Rm of 10.3%. For the R_f, we use the German Bunds' 10-year interest rate. For each project, we collect data from Bloomberg and use a weighted average yield from the previous six months prior to signing the contract.

The β_L is calculated as:

$$\beta_l = \beta_u \left[1 + (1 - t)\left(\frac{D}{E}\right)\right] \quad (2)$$

with β_u the unlevered Beta , E is the market value of equity for the firm; D is the market value of debt for the firm (see Table 2), and t is the Portuguese corporate tax rate, which was 25% at the time of these projects.

The β_u presents a difficult problem as these projects are not listed in the stock market. Therefore, we calculate the β_u with comparable firms in similar industry. We collect monthly data on the stock prices, dividends, and market values of five European firms in four countries. These firms are in the highway sector: Brisa (Portugal), Vinci (France), Abertis (Spain), plus Atlantia and Autostradia (both in Italy). To calculate the unlevered Beta , we first compute the stock and market returns and use a slope regression for each firm.

$$\bar{R}_{i,j} = \frac{Price_{i,j} - Price_{i,j-1} + Dividends_j}{Price_{i,j-1}} \quad (3)$$

where $\bar{R}_{i,j}$ are the returns of stock i in month j; $Price_{i,j}$ is the price of stock i at the end of month j; and $Dividends_j$ are the dividends on stock i in month j.

$$\bar{R}\ Market_{i,j} = \frac{Index_{i,j} - Index_{i,j-1} + Dividends_j}{Index_{i,j-1}} \quad (4)$$

where $\bar{R}\ Market_j$ is the return of the market $_i$ in month $_j$; $Index_{i,j}$ is the index $_i$ quote at the end of month $_j$; and $Dividends_j$ are the dividends paid on the index in month $_j$.

For a robustness check, we also use the unlevered Betas for the European transportation sector from the Damodaran online database. [3]

After calculating the β_L and the CAPM values, we also calculate the weighted average cost of capital (WACC) for each project:

$$r_{wacc} = \frac{E}{E+D} r_E + \frac{D}{E+D} r_D (1-t) \quad (5)$$

where E is the market value of equity in the firm; D is the market value of debt in the firm; r_E is the equity cost of capital (using CAPM values previously calculated); r_D is the debt cost; and t is

Corporate tax rate (25%). The equity and debt values for each project are based on Table 2. For debt cost, project loans are based on the Euribor interest rate (we use the average Euribor six months prior to signing each contract) plus each project spread (values in Table 2).

For the second research question, we use the β_l, the cost of equity (CAPM), and the WACC as the dependent variables. We expect to see how specific variables affect the project leverage, the equity return, and the capital cost. However, due to outliers, we drop two observations because two highway projects have a CAPM above 70% due to leverage close to 100%. Because the CAPM for most of the sample is below 25%, we exclude these two projects. This was confirmed when we test the residuals of our regressions. Therefore, our sample reduces to 18 projects.

The data are hand-collected from each of the 18 projects [from "Direcção Geral do Tesouro e Finanças" (or DGTF)]; the department of the Ministry of Finance responsible for managing and monitoring PPPs in Portugal, with information from financial annexes to the contracts]. The reports containing most of this data are the property of the Ministry of Finance. Although they are not publicly available, the previous Portuguese government granted us access (with a confidentiality agreement for individual cases).

We use the following model:

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[3] Available here: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/totalbeta.html

$$Y_{it} = \beta_0 + \beta_2 lenght_{it} + \beta_3 shareholders_{it} + \beta_4 payment_{it} + \beta_5 pfincrisis_{it} + \mu_i \quad (6)$$

Where:

Y_{it} is our dependent variable: the value of CAPM in each project.

Length is the size and length of the highway measured in kilometers. Despite the fact that length by itself does not necessarily mean complexity (usually more assess by the existence of tunnels, bridges, etc., see for instance Nogués & González-González (2014), we expect a longer highway to have a higher cost because of the positive relation to the dependent variables. We also expect, according to several studies (e.g., Kavussanos & Marcoulis, 1997) that size has an effect on the level of returns (there is also the issue of economies of scale in financing and operating a highway, see (Chu & Tsai, 2004; Odeck, 2008).

S*hareholder's* is a variable equal to zero when domestic firms own the majority of equity capital, while it equals one if foreign firms own it. A foreign stake can decrease the cost of capital because foreign firms might have access to better market conditions that provide better guarantees to lenders.

Payment equals zero if what is given to the PPP is based on service (demand), and equals one if the payment is based on availability. Large-scale capital-intensive projects tend to require heavy investments up front and only generate revenues in the long term (Roumboutsos & Pantelias, 2015). An availability payment consists of a fixed annual rent, as long as the asset is in condition to be used according to contractual requirements. This type of payment is expected to reduce the cost of capital, as the demand risk is allocated to the public sector. Therefore, there is lower uncertainty regarding long-term projections on revenues for a private party, which reduces the cost of capital. Blanc-Brude & Strange (2007), Sorge (2011), and Nguyen-Hoang (2015) also find that projects with revenues from tolls are riskier and have a higher cost of capital than those with revenues from the government.

Fincrisis is a dummy variable for the 2008 financial crisis that equals zero for credits if contracted before 2007 and one if contracted afterwards. This variable captures the effect of the financial crisis on the cost of equity and debt. Table 3 presents the statistics for the variables.

Table 3. Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Blpt	20	3.84	3.98	0.48	16.39
Bl Dam	20	3.41	3.12	0.73	14.41
CAPMpt	20	28.02	24.46	7.51	101.46
CAMP Dam	20	24.85	18.83	8.38	89.71
WACCpt	20	6.81	1.24	4.28	8.55
WACC Dam	20	6.42	0.59	5.38	7.23
lenght	20	159.65	116.63	23.00	520.00
Shareholders	20	0.25	0.44	0	1
Payment	20	0.30	0.47	0	1

Note:This table presents the statistics for the dependent and independent variables used in this study.
Source: authors.

5. Results and discussion

Using the Portuguese experience, we calculate the cost of debt, the CAPM, and the WACC for 20 highways that use project finance. The results are presented in Table 4. We observe that the cost of debt assumes values between 3 and 6% in most of these projects. This is the result of loan spreads of 1-2% and Euribor values at the time of these contracts (1999 to 2010) of around 3%-

4%. As the cost of debt is low (both reference rate and risk premium in the spreads), these projects are sustainable with high leverage values. Any debt above 70% of the total investment has a strong effect on the CAPM and WACC results.

Table 4. Project results

PPP	Own calculations of β_L			Damodaran β_L	
	RE	RD	WACC	RE	WACC
Norte	12.2	4.3	6.8	11.6	6.6
Oeste	14.1	3.6	6.1	13.8	6.0
Litoral Centro	20.2	3.4	4.3	31.2	5.4
Beira Interior	88.8	4.1	6.0	89.7	5.7
Costa da Prata	15.4	6.1	6.6	17.2	6.9
Algarve	12.8	6.2	6.4	16.2	7.1
Interior Norte	20.9	6.2	6.4	25.7	6.9
Beira Litoral e Alta	20.1	4.6	5.1	28.9	5.9
Norte Litoral	7.5	4.7	5.6	10.2	6.9
Grande Porto	8.9	4.6	4.8	15.3	6.3
Grande Lisboa	14.5	5.8	7.7	13.1	7.2
Douro Litoral	40.3	5.9	7.6	35.5	7.2
Transmontana	20.2	5.5	8.4	14.8	7.0
Douro Interior	75.6	5.4	8.2	48.8	6.7
Túnel Marão	18.4	4.9	8.2	13.6	6.7
Baixo Alentejo	19.4	3.0	7.4	14.1	5.8
Baixo Tejo	24.7	2.9	7.2	17.6	5.6
Litoral Oeste	47.9	3.5	7.2	33.6	5.7
Algarve Litoral	11.0	2.6	8.6	8.4	6.6
Pinhal Interior	56.2	4.1	7.8	38.1	6.2

Note:This table presents the results of the CAPM (using this paper's method and Damodaran values to calculate the levered Beta). *Re* stands for the CAPM values, *Rd* for the cost of debt, and *WACC* for the weighted average cost of capital. Source: own table (organized by the concession year).

The high debt raises issues about calculating the CAPM values. In most projects, the CAPM values are below 20%. If we assume (in a pre-2008 financial crisis) a risk-free rate of about 4-5%, this represents a true market risk premium of around 10% as compared to the 6% used to calculate the CAPM. The Beta values are high, but within the boundary of what financial markets followed in that period. As an example, the *Algarve* highway has a CAPM value of 12.8% (see appendix A, case 1).

Some projects show an extreme value for the CAPM. This is the case for *Douro Litoral* (40%), *Litoral Oeste* (48%), *Pinhal Interior* (56%), *Douro Interior* (76%), and *Beira Interior* (89%). How are these values possible, and how might they be considered in the financial world? The values represent the extreme leverage of these projects as *Beira Interior* and *Douro Interior* demonstrate (appendix A, case 2 and 3).

The extreme leverage in some projects (above 90% of debt) can generate equity return values that are unrealistic, indicating that using the CAPM could be misleading in project financing. Using the Beira interior concession, Table 5 shows how the levered Beta and the CAPM increased values as the firm increased its debt value. Values of debt above 80% of the capex clearly distort the levered Beta, as well as the CAPM. This distortion gives a misleading value for financial analysis. In this sense, the WACC values become much more reasonable. We see that in these projects, the WACC can range from 5% to a maximum close to 8%. The low cost of debt eliminates almost all the high values in the CAPM, see for example, the *Beira Interior* (appendix A, case 4)

Table 5 . Leveraged effects on CAPM

Debt - %	Debt – M€	Equity – M€	Levered	CAPM
10%	77	697	0.70	8.55
20%	155	619	0.77	8.95
30%	232	542	0.86	9.47
40%	310	464	0.98	10.15
50%	387	387	1.14	11.11
60%	464	310	1.38	12.55
70%	542	232	1.79	14.95
80%	619	155	2.60	19.74
90%	697	77	5.04	34.12
95%	735	39	9.91	62.88
97%	751	23	16.41	101.23
99%	766	8	48.91	292.80

Note: This table presents the levered Beta and the CAPM values for the Beira Interior concession assuming a risk-free rate of 4.4%, a tax rate of 25%, a capex of 774 M€, and a unlevered beta of 0.65. Source: authors.

Regarding the second research question as to what project variables affect the CAPM and WACC, Table 6 presents the results. The variable *length* has a positive coefficient that indicates the effect of the size and complexity of a highway on increasing the cost of equity and capital. This is the effect of greater uncertainty, as these highways are more complex, less standardized, and more prone to various contingencies. Lenders and investors appear less willing to extend loans to these projects and therefore demand a higher risk premium.

There is a strong effect from the financial crisis on the cost of equity and on the cost of capital. This effect can be explained by how the risk-free rate increased at the beginning of the financial crisis. However, the main reason for an increase in the CAPM is the increase in the cost of debt. In the case of the WACC, a reduction in leverage occurred for the projects signed after 2007. For example, *Tunel do Marão* and *Algarve Litoral* had low levels of leverage, when compared to previous projects.

Table 6. Results from regressions

Variables	(1) Blpt	(2) Bl Dam	(3) CAPMpt	(4) CAPM Dam	(5) WACCpt	(6) WACC Dam
enght	0.0023**	0.0017*	0.0594**	0.0346**	-0.0002	-0.0018
	(0.0009)	(0.0009)	(0.0204)	(0.0139)	(0.0011)	(0.0011)
Shareholders	-0.1933	-0.3066	-7.0198	-5.7063	0.5085	0.1131
	(0.3965)	(0.3738)	(6.2634)	(5.1506)	(0.3300)	(0.3197)
Payment	-0.0234	-0.0856	0.5946	-0.5478	-0.2781	-0.4398
	(0.3904)	(0.3754)	(5.5688)	(5.5501)	(0.4738)	(0.3799)
fincrisis	0.5207	-0.1563	10.0141**		1.8942***	
	(0.3160)	(0.3054)	(4.6067)		(0.3089)	
Constant	0.2207	0.7096*	8.7671	16.2446***	5.8058***	6.8505***
	(0.4377)	(0.3678)	(5.3649)	(4.9870)	(0.3892)	(0.3974)
Observations	18	18	18	18	18	18
R-squared	0.4021	0.1822	0.6096	0.2851	0.7383	0.2406

Note: This table presents the results of OLS tests that use the following dependent variables: *Blpt* stands for the levered Beta using the paper's method; *Bl Dam* is the levered Beta using the Damodaran values; *CAPMpt* is the CAPM values with this paper's method; *CAPM Dam* is the CAPM using the Damodaran values; and *WACCpt* is the weighted average cost of capital that uses this paper's method; and *WACC Dam* is the weighted average cost of capital. The robust standard errors are in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: authors

6. Conclusions

Over the last few decades, the Capital Asset Pricing Model (CAPM) has become the most popular tool in corporate finance to assess the cost of capital as a risk and return model. Large infrastructure projects have been developed based on Project Finance (PF) schemes, with high levels of debt. These very high levels of leverage raise doubts about the use of the CAPM. Practitioners use this model without proper consideration of the characteristics of project finance.

This paper uses Portuguese highway projects to address a new topic in the finance and funding of transportation infrastructure: what is the effect of the specific characteristics of project finance in the calculation and use of the CAPM? The high level of investment and leverage, with long maturities, determines the CAPM of a transportation project. How efficient is the use of CAPM under the financial conditions that characterize project finance? We first calculate the CAPM of each project by measuring the effects of investment and leverage. Second, we calculate several regressions to understand how project variables affect the CAPM and WACC.

We find that projects with high leverage, above 90%, often get unrealistic values from the CAPM. This is due to the effect of debt on the levered Beta and the subsequent effect of the levered Beta on the CAPM values. We also find that the cost of equity and the cost of capital tend to increase as projects become larger and more complex. This is the effect of greater uncertainty in which lenders and investors perceive higher risk and demand increased risk premiums. The 2008 financial crisis had a strong effect on increasing the cost of equity and the cost of capital. This is the consequence of the financial market crises. When investors have less liquidity to invest, they are thus more conservative and less willing to make loans on projects with high levels of leverage.

Despite the popularity of the CAPM in corporate finance, transportation projects (using project finance schemes) must be prudent with this tool when measuring shareholders' equity returns.

Extremely leveraged projects produce misleading values in the CAPM. Project finance's specifications demand the use of different approaches to traditional corporate finance.

Further research on this topic is still needed. We have accounted for some limitations in the use of the CAPM in project finance. Yet, a large data set of highway projects from several countries, with substantially more "corporate finance" firms to compare the estimation of the Betas would be relevant. The limited data in this paper prevent us from addressing other issues, such as the effect of project and contract characteristics. Also, future research could expand our analysis to other transportation sectors where PPPs and project finance have also been extensively used, such as railways, ports, or airports. Finally, we should discuss if the Betas used in the CAPM should be adjusted to the specifications and the higher debt levels of project finance when compared with the corporate finance that follows the new trends in finance, such as the "three factor" CAPM from Fama and French.

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Appendix A

Case 1: a highway with a 12.8% CAPM (*Algarve*)

$\beta_l = 0.4\left[1 + (1 - 0.25)\left(\frac{232}{63}\right)\right]$,

meaning $\beta_l = 1.5$

and $r_E = 5.3\% + 1.5\ (10.3\% - 5.3\%) = 12.8\%$.

Case 2: a highway with 89% fo CAPM (*Beira Interior*)

$\beta_l = 0.65\left[1 + (1 - 0.25)\left(\frac{747}{27}\right)\right]$,

meaning a $\beta_l = 14.3$

And $r_E = 4.4\% + 14.3\ (10.3\% - 4.4\%) = 89\%$.

Case 3: a highway with 76% CAPM (*Douro Interior)*:

$\beta_l = 0.9\left[1 + (1 - 0.25)\left(\frac{753}{47}\right)\right]$, meaning $\beta_l = 11.7$

and $r_E = 4.2\% + 11.4\ (10.3\% - 4.2\%) = 76\%$.

Case 4: WACC for *Beira Interior*:

$r_{wacc} = \frac{27}{774} * 89\% + \frac{747}{774} * 4.1\% * (1 - 0.25) = 6\%$.