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Financial exposure and technology innovation investment: Measuring project results in Brazilian commodity industries

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Financial exposure and technology innovation investment

Measuring project results in Brazilian commodity industries

Exposição financeira e investimento em inovação tecnológica

Mensuração de resultados de projetos em indústrias brasileiras de *commodities*

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Abstract

Purpose – The purpose of this paper is to identify, measure and optimise financial risk and its effect on returns from innovation projects on an accrual basis and on a cash basis in a commodity industry.

Design/methodology/approach – A hypothetical case study, based on a real case, of a petrochemical commodity industry in Brazil was analysed with commodities pricing rules based on actual contracts. Earnings at risk (EaR) and cash flow at risk (CFaR) measures were applied, as well as a metric proposed in this paper called cash balance at risk (CBaR).

Findings – The paper demonstrates that financial risk measurement and optimisation are important issues in the decision-making process in the petrochemical industry. EaR, CFaR and CBaR measures are helpful when used alongside standard procedures of project evaluation. The findings also show that innovative technologies, in certain conditions, may act as "natural hedging". It was found that the time delay between revenues and expenses leads to financial risk exposure to changes in prices and foreign exchange rates. Projects can use financing and hedging to boost their results.

Originality/value – An innovative project was compared with an expansion project in a petrochemical industry. A model for petrochemical commodities contract pricing was added in an analysis that included financing and hedging. The findings in this paper suggest that it is important to consider financial risk measures in project evaluation.

Keywords Corporate risk, Risk management, Project evaluation, Petrochemical commodity industry, Stochastic simulation

Paper type Research paper

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Resumo

Objetivo – O objetivo deste trabalho é identificar, medir e otimizar o risco financeiro e seus efeitos sobre os resultados de projetos com inovação, tanto na perspectiva do regime contábil quanto do regime de caixa, em uma indústria de *commodities*.

Abordagem – Um estudo de caso hipotético, baseado em um caso real de uma indústria petroquímica brasileira, foi analisado com regras de precificação de *commodities* baseados em contratos reais. As métricas *Earnings at Risk* (EaR) e *Cash Flow at Risk* (CFaR) foram utilizadas, assim como uma métrica proposta neste trabalho, denominada Cash Balance at Risk (CBaR).

Resultados – Este artigo demonstrou que a mensuração e otimização do risco financeiro são questões importantes no processo de tomada de decisão em uma indústria petroquímica. As medidas EaR, CFaR e CBaR se apresentaram como contribuições ao processo padrão de avaliação de projetos. Os resultados também demonstraram que inovações tecnológicas, em certas condições, podem funcionar como um "*hedge* natural". Foi verificado que descasamentos temporais entre recebimentos e despesas geram uma exposição financeira a oscilações em preços e em valores de moedas estrangeiras. Financiamento e *hedge* podem ser utilizados em conjunto para aprimorar resultados de projetos.

Originalidade/valor – Um projeto com inovação foi comparado com um projeto de expansão em uma indústria petroquímica. Foi realizada uma analise de risco que agrega ao financiamento e ao *hedge* o uso de contratos de precificação de *commodities*. Os resultados desse projeto demonstram que é importante considerar medidas de risco financeiro nas avaliações de projetos.

Palavras Chave Risco corporativo, Gestão de Risco, Avaliação de Projetos, Industria de Commodities Petroquímicos, Simulação Estocástica

Tipo de Papel Artigo de pesquisa

Introduction

When a company chooses to invest in new technologies, it evaluates the financial risks of the project considering the already existing financial risk structure. Risk is understood as the association between a possible loss of value and the presence of uncertainties (Ilevbare *et al.*, 2014), and there are several ways of managing this financial risk. ISO 31000 (ISO, 2009) defines risk as the consequence of an uncertainty on company objectives. It also recommends the use of the Monte Carlo simulation technique for risk measurement to handle complex risk situations. Wu and Ong (2008) state that there is a fruitful relationship between large-scale technology projects and risk management techniques, but there is a gap in company risk management practices and many high investment projects fail because of poor risk management. Although most companies are vulnerable to uncertainty and risks, those that operate with new technologies seem to be prone to higher risks because they find themselves in a spot where the unknown is prominent.

According to Miorando *et al.* (2014), financial exposure is one of the factors that affect decision making in technological innovation. Financial exposure comes from uncertainties in variables such as foreign exchange rates and commodity prices. Risk management techniques used by financial companies can be adapted for use by non-financial corporations. One way to evaluate financial risk is by using earnings at risk (EaR) and cash flow at risk (CFaR) measures, as described by Denton *et al.* (2003), Anderson and Davison (2009) and Maisano *et al.* (2016). These measures are similar to the value at risk (VaR) measure which is widely used by the financial sector.

Traditional project analysis approaches such as net present value (NPV) and "strengths, weaknesses, opportunities and threats" are unable to provide a complete evaluation of the synergy between proposed projects and the current company structure. Traditional approaches fail to consider the relationship between new investment and company debt, revenues and expense patterns. This relationship is hidden in correlations of financial variables that are not considered in traditional analyses. Often, the financial impact of the new investment is evaluated as an independent business. This is because it is difficult to calculate correlations between the forecasted performance of new investment and current company results. However, this kind of problem may be solved more easily in commodity industries because the prices of the final products, supplies and energy in the new projects may be correlated to current prices and the other financial risk factors of the business. Here, we suggest some financial strategies to manage risks which are not often considered in the traditional evaluation of NPV: the combination of different financial tools, such as derivatives, during project elaboration to optimise the risk-return relationship to obtain a better mean-variance result for the company after the project is accomplished.

In 2015, Brazilian companies exported up to 191 billion dollars worth of products (MDIC, 2016a), and imported 171 billion dollars worth (MDIC, 2016b). Commodities represent around 60 per cent of Brazilian exports (UNCTAD, 2014). Inserted in this perspective, we use a hypothetical company model, inspired by a real case, that imports and processes commodities and produces final products that are also petrochemical commodities. The hypothetical company has to choose a project to invest in, in order to increase revenues: a project with a technology already dominated by the company; or a project that invests in a new technology. Each alternative has its own expected cash flow, which has a specific synergy with the cash flow that the company expects with its current products. The aim of this paper is to evaluate the synergies and risk management strategies of two such projects (an innovative project and a non-innovative project) in order to improve decision making.

Innovation and financial risk

Innovation, challenges and financial risk in Brazil

According to Silva (2005), Brazilian companies which make intensive use of technology have a particularly high overall mortality rate for two main reasons. The first is the lack of competence in planning before entering the market. The second reason is managers' lack of skills in dealing with market risks. Hyytinen *et al.* (2015), using data from Finnish start-ups, claim that innovative start-ups may face great uncertainty with intertemporal cash flows.

According to SEBRAE (2013), small and medium-sized enterprises have a high survival rate in the first years of their existence. However, after three years the survival rate falls considerably. According to the executive secretary of *Associação Nacional de Pesquisa e Desenvolvimento das Empresas Inovadoras* (ANPEI), Brazilian National Association for Research and Development of Innovative Companies, small companies that grow to the medium size category in Brazil stop innovating in order to survive because the new tax regime which they have to cope with impels them to worry about payroll and taxes alone (Drska, 2014). ANPEI also reveals that only 3.2 per cent of medium-sized companies consider innovation a priority for the next five years (Drska, 2014).

According to Bittar *et al.* (2014), large Brazilian companies usually have difficulty investing in technological innovation for the following reasons: the lack of staff qualified in sciences and engineering; the lack of desire to innovate due to risk aversion; and the absence of pro-innovation elements in the business culture of the companies. Insofar as risk aversion, accurate financial risk measurement of technological innovation projects may provide an important contribution to overcoming this barrier that also hinders the development of an innovation culture.

The financialization of commodity market

Between 2004 and 2008, institutional investors started investing more in commodity futures (Tang and Xiong, 2012), and since the 2008 crisis, a rise in the equity-commodity correlations has been observed (Büyükşahin and Robe, 2014). This phenomenon was called the "financialization of commodity market". It was empirically investigated by several papers, such as Ederer *et al.* (2016), Gogolin and Kearney (2016), Pradhananga (2016) and Tzeng and Shieh (2016). A theoretical work that explains the phenomena was developed by Basak and Pavlova (2016) and they report three main findings: the presence of institutional investors raises commodity future prices; the "financialization" makes the volatility and correlation to equity markets become stronger; and, finally, the commodity spot and inventory prices go up with commodity market financialization. These findings highlight the importance of risk management studies in commodity-intensive companies. Furthermore, Adams and Glück (2015) analysed whether this "financialization of commodity markets" would be temporary, and they predicted that relationships between commodities and the stock market would remain high in the future. This would keep the market speculative and risky. Recent works proposing innovations in commodity market models demonstrate that "financialization" is a trend. These models include "market financialization" and market speculation (Li *et al.*, 2013; Frankel, 2014; Cifarelli and Paladino, 2015; Wang *et al.*, 2015; Drachal, 2016).

Foreign exchange rate financial risk exposure

Dominguez and Tesar (2006) study exposure to foreign exchange rate risk in companies in several emerging markets and industrialised countries around the world. They found a high correlation between the performance of companies in these markets and the foreign exchange rate. The observed effects are greater in small businesses and in export-import companies, which adjust their behaviour dynamically. In the industrial area, a direct correlation between company size and exposure to foreign exchange rate risk was found. Choi and Jiang (2009) show that as companies become more multinational, their foreign exchange rate risk exposure reduces.

Ye *et al.* (2014) carried out research complementing the work of Dominguez and Tesar (2006), analysing the influence of countries' foreign exchange rate policies on company results. They found that regardless of the countries' foreign exchange rate regimes, companies are highly exposed to changes in foreign exchange rates. Notwithstanding, in countries with fixed foreign exchange rate policies, companies suffer a higher financial impact due to changes in the foreign exchange rate, when compared to the financial impact on companies based in countries where the foreign exchange rate regime is floating.

Approaches to corporate financial risk measurement

Project evaluation and project management have developed into project portfolio management. This new concept considers the relationship between new projects and the already existing projects in companies, since "it will be the total risk that will ultimately impact on the project's operational risk and that of the parent firm's expanded project portfolio" (Paquin *et al.*, 2016). Lin *et al.* (2008) carried out theoretical mathematical research (verified by empirical tests) on the relationship between decisions relating to investment, financing and hedging, and their results indicate that the overall results should not be evaluated without these three aspects, otherwise it would lead to biased estimates and to potentially spurious relationships. This paper works on both principles, evaluating the joint results of investment, financing and hedging as the impacts to "total risk" in companies.

Insofar as single project risk analysis, several works have been published in the area of combined heat and power generation (Gómez-Villalva and Ramos, 2003; Wickart and Madlener, 2007; Kettunen *et al.*, 2010; Alipour *et al.*, 2014; Cano *et al.*, 2014; Maurovich-Horvat *et al.*, 2016). Although this line of research does not consider the principle of impacts on the "total risk" of a company, they demonstrate the use of multi-stage evaluation in the project management and point to directions for further development of this research. This multi-stage evaluation is used to evaluate the flexibility of choosing which kind of energy source to consume. In contrast, in our problem, it is not possible to make great changes in the production once the project has been implemented. However, our hedging strategy may also be elaborated as a flexible multi-stage strategy that can be periodically (e.g. yearly) updated, so that it is suitable to use the same mathematical tool in an application, different from those previously discussed.

Another field in project evaluation that considers risks as a key issue is real options (RO) valuation. The RO approach is used to evaluate projects with sunken costs, uncertainties, and managerial flexibility. In our literature review, the most relevant works and recent research includes that of Benaroch (2002), Bardhan *et al.* (2004), Wu and Ong (2008), Ghosh and Troutt (2012), Buhl *et al.* (2013), Ghosh and Li (2013) and Arasteh (2016).

The measurement of corporate financial risk in this paper uses metrics based on financial market techniques. This work focusses on foreign exchange rate risks and commodity price risks. These risks are classified in the literature as market risks (other financial risks are credit risk and liquidity risk). The Corporatemetrics™ method from Riskmetrics Group (1999) is an open method used by this group to measure the financial risk in non-financial companies. It calculates the CFaR and the EaR, which are adaptations of the VaR measure. These two measures, CFaR and EaR, are complemented here by a new proposed metric: the company's lowest expected cash balance in a given period, referred to here as cash balance at risk (CBaR). The metrics may be calculated using various methods, such as the Monte Carlo simulation, historical simulation and parametric methods, and they represent the worst expected result (or the worst expected loss) over a given period (time horizon) for a specified statistical confidence level.

The calculation of CFaR and EaR metrics for non-financial companies is recommended by international consulting firms such as McKinsey (Pergler and Rasmussen, 2013); however, these metrics should be adjusted to the company business model. One important step in calculating CFaR and EaR is the identification and prioritisation of risks and the modelling of exposure. According to Pergler and Rasmussen (2013), the risk measures allow: the company to determine a quantitative "risk appetite"; a clear comparison of the risks related to the company's different projects or activities; to foster a dialogue on uncertainties and the trade-offs in managing them; to remove biased slopes of the strategic planning process; and ultimately to generate value for the company through optimisation of the risk-return relationship, combining decisions to reach better financial/accounting performance for a given risk level (which may be the current one unknowingly assumed by the company) so that expected returns are maximised.

Decision making when there are project options

The next step is the decision-making process. At this stage, the selection of new projects that a company can invest in is carried out based on the comparison of expected performance and risk. This comparison is carried out here using: the risk-adjusted performance; the interactions of each project with the company's existing business; and the possible financial strategies that the company can use to improve results (with financial derivatives or other financial market tools).

Several decision criteria can be used in this decision-making process. Although many factors influence the decision when a company evaluates a portfolio of projects, in the financial risk approach, the most frequently used are the following two criteria: optimise the performance in an adjusted risk approach, which means that, for a specific level of expected risk or risk tolerance, the company chooses the strategy of higher expected returns; minimise the risk level as much as possible. In either criteria a hedge is established whenever a risk exposure is mitigated by a financial decision (e.g. commodity options trading). The first criterion would establish only a limited degree of hedging, while the second criterion would try to hedge all possible hedging exposure.

Allayannis and Ofek (2001) analyse the use of foreign currency derivatives by non-financial companies in the S&P 500 (Standard & Poor's index). They found that the decision to carry out a hedge strategy can be explained by a number of variables, but the amount of derivative contracts depends exclusively on the volume of international transactions. They also found that these companies do not use derivatives for speculation. Based on this finding, this paper assumes that derivatives and other financial tools will be used only for risk mitigation purposes, as it seems to be the strategy employed by the biggest US companies. The literature reports and discusses risk management strategies for foreign exchange rates, such as the works of Hsu *et al.* (2009), Afza and Alam (2011), Disatnik *et al.* (2014), Kouvelis *et al.* (2013), Palzer *et al.* (2013), Zhou and Wang (2013), Chen and King (2014), Fabling and Grimes (2014) and Rampini *et al.* (2014).

In the next section, an industrial case study is described in which two projects, one of innovation and another of expansion, are evaluated for risk.

Commodity industry case study

The case studies are hypothetical due to confidential and proprietary reasons; however, they are based on a real petrochemical company that buys a specific petroleum fraction and basic petrochemicals as raw material and processes them, producing 270,000 metrics tons per year of intermediate petrochemicals. The products are sold on both the national and the international markets. Some of the contracts with customers incorporate changes in supply prices in the prices of final products, generating a so-called "natural hedge" for price changes. However, there is often a time delay between when it pays for raw materials and receives revenue from sales which, when combined with changes in prices and foreign exchange rates, may have a strong influence on its cash flow. Due to this time delay, supply price changes may influence the cash flow even with the "natural hedge" of the contracts.

The company wants to invest and there are two possible projects to choose from to increase its revenues. One is the "expansion" project, an investment with little innovation to expand the plant, creating a new unit with a more efficient process in which less raw material would be required per unit of product. This expansion would involve small technological changes compared to the current plant technology, which involves little technological risk. The second possibility is the "innovation" project, consisting of the creation of a new productive unit with completely different technology, in which the company would use a new and cheaper raw material.

The company must also decide how to obtain the loan for project implementation. It has two options, a loan in the national currency (real) or in a foreign currency (US dollar). Both projects are the same size, and the loan in dollars has a lower interest rate than the loan in reals. Both projects can be implemented within one year and should be evaluated in the first 12 months after implementation, a period for which the company has already forecasted prices and sales quantities.

Special contracts, known as (*Adiantamento sobre Contrato de Câmbio* (ACC) – advance against exchange) and (*Adiantamento sobre Cambiais Entregues* (ACE) – advance against draft presentation), are used to aid export companies and they are regulated by the Central Bank of Brazil for hedging and financing purposes. Both loan money in a domestic currency is backed by exports. However, the bank charges are different for each kind of loan and they change over time. The ACC operation is a loan that can be given even before production using expected sales, whereas ACE, while similar, is settled only after the product is transported to the customer. For our evaluation purposes in this work, the company only has ACC and ACE as financial mechanisms to manage foreign exchange rate risks exposure. In the project evaluation here, ACC is settled in the first month of evaluation as a percentage of the expected export sales for the whole year and ACE is taken monthly as a percentage of each month's exports. If the two kinds of contract are to be used, then ACE will be a percentage of the exportation percentage not covered by ACC.

The company works with a mix of raw materials that are processed to produce a mix of final products. Each of the chemical supplies and final products contracts has specific clauses for price changes. Generally, for each commodity, there is a fixed dollar value (called premium value) added to a floating dollar value which is calculated based on the international market prices of commodities that are used as references for prices. For domestic sales, the contracts use the average USD-BRL exchange rate of the month prior to delivery, while international contracts are priced at the current dollar exchange rate. All purchases are paid for on delivery, revenues from domestic sales take a month to be received, and revenues from international sales take two months to be received. As stated earlier, this time delay between revenues and expenses, in addition to the seasonal pattern of company sales and the changes in market prices, result in cash flow uncertainties.

The data used in these case studies are shown in Table I. The company produces three products, P1, P2 and P3, and uses three raw materials, RM1, RM2 and RM3. Each sold final product price is based on fixed costs, on the cost of the raw materials, on transport costs, on taxes and on a fixed value, which will result in the company profit margin. Raw materials are priced by the prices of reference commodities (RC1, RC2 and RC3) plus a premium. Project Innovation will work with a new raw material (RM4) which is priced using a different reference commodity (RC4).

Measuring EaR, CFaR and CBaR

The evaluations in this paper are measured on an accrual basis for the net earnings (calculated from the income statement for one year) and on a cash basis for the cash flow (and the cash balance). The simulations consider projects with different technological innovations and allow the assessment of expected results and risks in the company's net income and cash flow. The average of the different scenarios in a Monte Carlo simulation is used as the expected result and the risk metric is evaluated in a statistical confidence level α. The following metrics are generated: EaR, corresponding to the α percentage of net income results accumulated until the last evaluated period; CFaR, corresponding to the α percentage of the total cash flow until the last evaluated period; and CBaR, corresponding to the worst result, among all evaluated periods through the whole evaluation horizon, of the α percentage of the available cash balance. Figure 1(a) describes this procedure.

The risk measurement and decision making

In this paper the method proposed to evaluate the expected results and the financial risk follows five steps: (1) Monte Carlo simulation of chemical supplies and final product prices and quantities and Monte Carlo simulation of foreign exchange rate and any other uncertainty that may affect the income statement and cash flow of the company; (2) calculation of the expected cash flow and the company's expected profit; (3) calculation of EaR, CFaR, CBaR and any other risk metric; (4) analysis of the set of simulations for a given project study; and finally (5) a comparison of the different projects. The Steps 2, 3 and 4 are repeated using computational mathematics in a search for the best financial options decision-set before Step 5 is applied.

The application of this method supports the decision-making process for investing in a technological innovation project. It does not take into account qualitative issues and its quantitative scope is restricted to short and medium range financial risk management, and so it does not replace other evaluation techniques. Here the terms "simulation", "project" (or "reference case") and "scenario" refer to the results generated by the Monte Carlo approach; the innovation or expansion project to be undertaken by the company, including the no project possibility, i.e., the reference case; and different market expectations for the foreign exchange rate and commodity prices, respectively. Market expectations for volatilities were defined using historical data and market price drifts were defined as zero. A schematic representation of the method is shown in Figure 1(b), where "fin." stands for financial.

Company data before investment in projects			
Seasonality. Expected sells variation for each month (based on annual sells divided by 12)			
Jan + 5%	Feb +10%	Mar +15%	Apr + 5%
May + 0%	Jun + 0%	Jul + 0%	Aug − 5%
Sep − 15%	Oct − 10%	Nov − 5%	Dec + 0%
Market Data			
Expected price at start of evaluation (USD/ton)	RC1 = 1,000	RC2 = 1,300	RC3 = 500
Expected drift of market prices	RC1 = 0%	RC2 = 0%	RC3 = 0%
Expected volatility of market prices	RC1 = 10%	RC2 = 12%	RC3 = 11%
Fixed premium for customers (USD/ton)			
	P1	P2	P3
National	1,300	100	20
Exportation	400	400	0
Fixed premium of suppliers (USD/ton)			
	RM1	RM2	RM3
National	300	400	0
Importation	400	–	–
Used tons of RM for 1 ton of P produced			
	RM1	RM2	RM3
P1	0.85	0.15	0
P2	0.64	0.11	0.25
P3	0.85	0.15	0
Operational data			
Ratio of output by product	P1 = 65%	P2 = 31%	P3 = 4%
Exportation ratio	P1 = 13%	P2 = 7%	P3 = 9%
Importation ratio	RM1 = 53%	RM2 = 0%	RM3 = 0%
Business data			
Expected annual production (tons)			2.7×10^5
Expected sells volatility			11%
Expected USD-BRL exchange rate at start of evaluation			2.5
Expected drift in USD-BRL exchange rate			0%
Expected volatility in USD-BRL exchange rate			3.80%
Tax 1 over nationally sold product			10%
Tax 2 over nationally sold product (charged after Tax 1)			18.65%
Tax over profit			24%
Tax over net-profit[a]			0%
Other variable costs 1 (based on revenue) (BRL)			1%
Logistics costs (for each ton sold) (BRL)			200
Monthly fix costs (BRL)			4×10^6
Monthly remuneration of company cash			0.45%
Emergency loans monthly interest rate (in scenarios of negative cash balance)			1.10%
ACE and ACC monthly interest rate			0.70%
Expected annual dividends (BRL)[b]			90×10^6
Projects data			
Project Expansion investment costs (BRL)			120×10^6
Project Innovation investment costs (BRL)			120×10^6
USD loans annual interest rate			4%
BRL loans annual interest rate			8%
USD-BRL exchange rate in the moment of loan			3.00
Project increase in production (both projects)			120×10^3

Table I.
Case study data

(*continued*)

Project Expansion economy in RM1 use	10%
Project Expansion economy in RM2 use	5%
Project Innovation use of RM4 in substitution of RM1	100%
Fixed RM4 premium of suppliers (USD/ton)	470
Expected RC4 price at start of evaluation (USD/ton)	395
Expected RC4 drift of market price	0%
Expected RC4 volatility of market price	7%

Notes: [a]In Brazil there is a tax over net-profit, but the Brazilian Government usually do not charge this tax for petrochemical companies as an incentive to this market; [b]dividends are paid in February, July and October in equal parts

Table I.

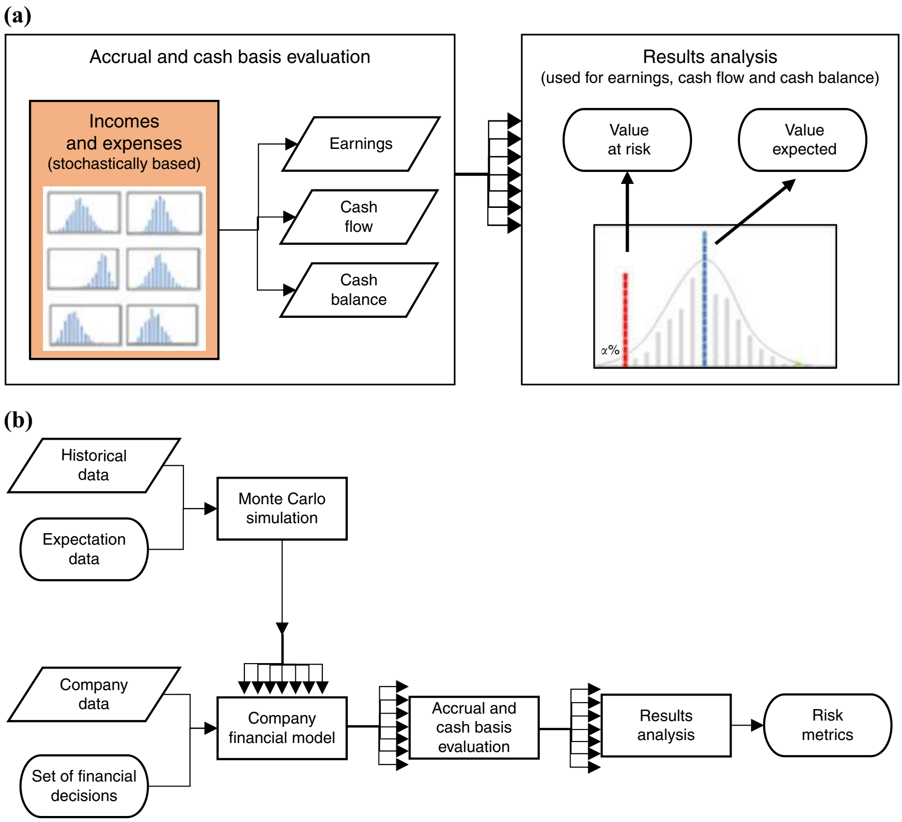

Figure 1.
Risk metrics generation

As stated earlier, three risk metrics were considered: EaR, CFaR and CBaR. All the three risk metrics are calculated monthly with a 95 per cent statistical confidence interval and on a twelve-month time horizon. The way CBaR is measured allows the manager to avoid a lack of available cash in any period of the evaluated time horizon. That is, using CBaR guarantees that no specific period of time is overlooked when searching for the best final result. Summing up, this paper uses EaR, which is based on the accrual basis results (profit or loss) in the income statement of one year. The second risk metric is the CFaR, which is computed based on a monthly cash basis results over a twelve-month period. Finally, there is the CBaR, which is the worst expected cash balance from the first until the last evaluated period.

Another common risk measure in the literature is the difference between the expected value and the worst scenario within a statistical confidence interval. It has become a standard in financial companies through the use of VaR and conditional-value-at-risk. Our metrics did not use this method because a negative result is an uncommon scenario in a non-financial company, and so in most scenarios, it would measure "how much a company may not earn", an unnatural result when compared to "in the worse scenario, the company will earn". This metric construction is even more important in CBaR measurement because any non-positive scenario will reflect the unwanted results. This must be taken into account when interpreting numeric results as it leads to different interpretations of the same number (e.g.: positive risk results can be extremely bad).

Stochastic method for the generation of scenarios

To carry out the simulations, the following risk factors were identified: sales quantities, commodity prices and the foreign exchange rate. The simulations are calculated using the geometric Brownian process, as in Postali and Picchetti (2006) and Lin (2008). In Equation (1), S_i is the price or quantity of the variable i in a given time t, μ is the expected growth rate, and σ is the monthly volatility. The variable dz corresponds to a Wiener process:

$$dS_{i,t} = \mu_{i,t} \cdot S_{i,t} \cdot dt + S_{i,t} \cdot \sigma_i \cdot dz \quad (1)$$

The Monte Carlo simulation is applied to the international prices of commodities that are used as reference prices for contracts. Based on these reference prices, supply and final product prices are calculated using Equation (2). In Equation (2), S is the reference price, P_j is the supply or final product j price, Vf is the premium (a fixed value which represents some specific costs and the profit margin), β is the weight of the price of each basic commodity that sums up the composition of the price of each final product, and r is the number of basic commodities:

$$P_{j,n,z} = Vf_j + \sum_{i=1}^{r} S_{i,n-1,z} \cdot \beta_{i,j} \quad (2)$$

The amount of sales also follows a stochastic process similar to Equation (1); however, the growth rate is set to zero because production is considered to fluctuate around an average level. The Monte Carlo simulation calculates results from the quantities, prices, taxes and other costs. Each of these results is calculated on cash basis and on accrual basis. The cash basis results are computed considering a delay between expenditure on purchases and product revenues.

Decision making of financial choices

Each financial decision taken will modify the results of the metrics described above, and therefore when each project is modelled, different decisions based on a risk management criterion can be compared. For example, a minimisation of CBaR (or CFaR or EaR) for each project can be carried out. The best strategy for a given level of risk can also be calculated; e.g., it is possible to maximise expected returns for a given level of expected risk. The choice of the decision-making criterion depends on company strategies, which includes the firms' degree of risk aversion.

In this paper, the company aims to minimise cash balance risk and therefore chooses ACC, ACE and long-term loan strategies to achieve the less risky achievable decision-set for each project. The optimisation method used is the generalised reduced gradient (GRG) method which solves non-linear problems and which was also used by Maiti *et al.* (2009) to solve a stochastic inventory price-dependent problem.

Project impact on financial risk structure

The risk management approach applied here to evaluate projects provides additional information and can be used together with other tools of project assessment, such as the traditional NPV and internal rate of return methods. The aim of this is to assist the decision-making process and evaluate not only the risk structure of a particular project but also provide information about the project impact on the financial exposure of the company as a whole.

Each project is evaluated for its impact on the whole business, and in order to achieve this, the outcomes of each project are evaluated as the difference between each project result and the results of the reference case (the case in which no project would be carried out). For example, if the reference case has an EaR of 100 million USD and one project has an EaR of USD130 million, the EaR outcome of this project will be presented as a USD+30 million result. This result is called an "impact".

Finally, once the results of each project are computed, a classical sensitivity analysis is applied to each optimised decision and to the reference case. The aim of the sensitivity analysis is to verify whether the optimised decision retains its characteristics in other market drift scenarios.

Results and discussions

All results presented here are in millions of Brazilian reals unless otherwise stated. Where results are presented in American dollars, the equivalence was calculated with an exchange rate of 2.5 USD/BRL, the same rate at the start of the evaluation. The method focus is on financial risk management, and therefore other aspects are not discussed in this hypothetical study case.

Reference case (no project) analysis

For the reference case, positive expected earnings were found in the region of 80 MM BRL (USD32 MM) with an EaR of almost 30 MM BRL (USD12 MM), an expected negative cash flow, an expected low positive cash balance and a highly risky cash balance, which could reach negative values in several (seven) months. Figure 2 represents the monthly expected values graphically (continuous lines) obtained for all projects, along with their risk measurements (dotted lines), i.e., the worst expected scenarios.

Despite the fact that the EaR is positive for the reference case, the CBaR is negative, which means that there is a high probability that the company will present a negative cash balance in cumulative months. This negative CBaR may become a liquidity problem for the company. The reference case was also analysed for two different USD-BRL exchange rate scenarios, a monthly increase of 1.5 per cent (BRL depreciation scenario) and a monthly decrease of 1.5 per cent (BRL appreciation scenario). All three scenarios were used to compare the innovation investments and the annual results for these simulations and all other sensitivity tests are shown in Table II, where "min." indicates the case where the minimised risk decision-set is applied.

The analysis of the effects of the USD-BRL exchange rate on the reference case shows the impact of foreign exchange rate fluctuations on the company business. USD appreciation leads to an increase in the net income of the company, but successive dollar appreciation also leads to a reduction of available cash. It was found that this happens because of the time delay in the impact of the foreign exchange rate in outflows

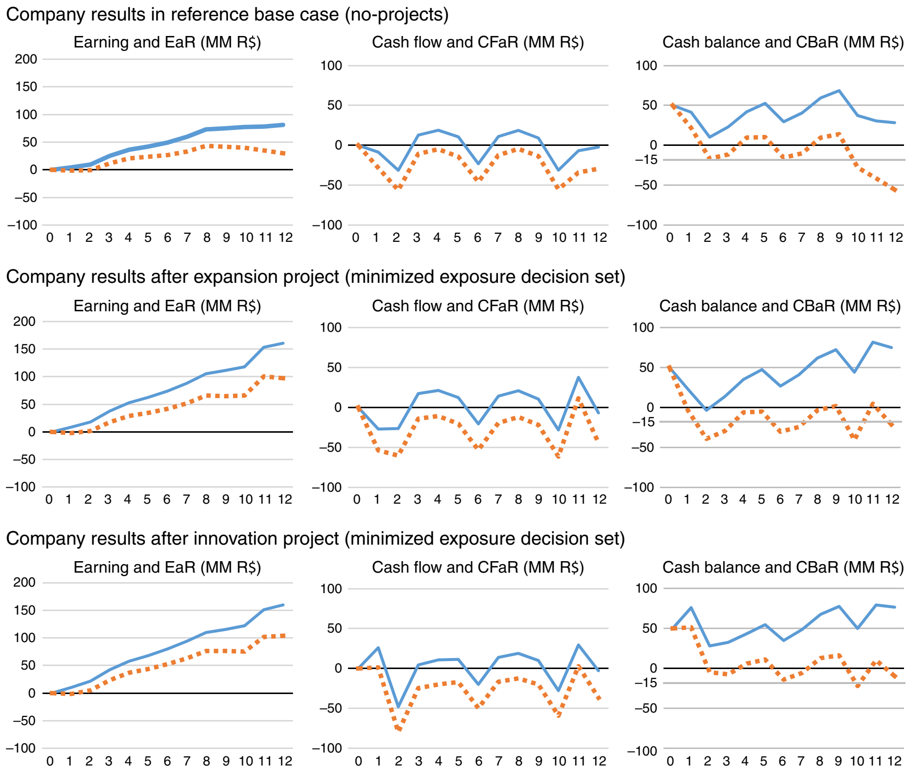

Figure 2.
Monthly expected values and risk metrics of results of all projects

and inflows as discussed previously. In order to confirm this, an additional analysis was made where a foreign exchange rate trend is simulated from the beginning of the evaluation and zeroed after the eighth period. It was found that although the expected net income increased, the final results of the cash balance analysis became equivalent to the net income results, confirming the interpretation of the previous results.

Projects analysis

For each project, three risk management decisions were evaluated: the percentages of loans taken out in USD and in BRL; the number of ACC contracts in the first month; and the number of ACE contracts after the ACC debt is paid. These decisions were evaluated minimising the annual value of CBaR. As a result, the minimal foreign exchange rate risk for the Innovation project was reached with an ACC of 45 per cent of the value of annual expected exports, with a 100 per cent ACE for all the remaining exports, and with 100 per cent of the loan taken out in dollars. In the Expansion project, however, the minimal risk was reached with no ACC contract, a 100 per cent ACE for all the remaining exports, and 100 per cent of the loan taken in dollars. The results are shown in Table II, "min. expansion" and "min. innovation", where "min." stands for minimised risk.

The results in Table II show a comparison between non-minimised risk decision-set and minimised risk decision-set evaluation for each project and the reference case. The results obtained with the non-minimised decision-set show distinctly worse results than the risk minimised decision-set results. These results show the importance of financial exposure optimisation for the project evaluation process. Because ACC and ACE

Table II. Annual results with sensitivity analyses and zero drift monthly CBaR measurement (million BRL)

	Reference			Min. expansion			Min. innovation		
Δ USD-BRL rate	−1.5%	0.0%	1.5%	−1.5%	0.0%	+1.5%	−1.5%	0.0%	+1.5%
Expected earnings	68	81	94	152	161	169	151	160	168
EaR	23	29	37	96	97	99	101	104	105
Expected cash flow	−16	−22	−31	24	25	24	25	27	28
CFaR	−88	−106	−128	−60	−71	−90	−51	−60	−73
Expected cash balance	34	28	19	74	75	74	75	77	78
CBaR	−38	−56	−78	−36	−41	−59	−11	−22	−35

	Non-min. expansion	Non-min. innovation	Min. expansion contribution			Min. innovation contribution		
Δ USD-BRL rate	0.0%	0.0%	−1.5%	0.0%	1.5%	−1.5%	0.0%	1.5%
Expected earnings	158	157	+84	+80	+75	+82	+79	+75
EaR	91	96	+73	+68	+62	+78	+74	+68
Expected cash flow	5	8	+40	+47	+55	+40	+49	+58
CFaR	−101	−85	+28	+35	+37	+38	+47	+55
Expected cash balance	55	58	+40	+47	+55	+40	+49	+58
CBaR	−63	−45	+2	+15	+19	+27	+34	+43

Monthly CBaR[a]	0	1	2	3	4	5	6	7	8	9	10	11	12	Yearly CBaR
Reference	50	22	−17	−11	10	10	−16	−10	10	14	−28	−41	−56	−56
Min. expansion	50	−4	−39	−29	−6	−5	−30	−25	−4	2	−41	5	−21	−41
Min. innovation	50	51	−5	−8	6	11	−14	−6	13	16	−22	10	−10	−22

Note: [a]Shaded numbers represent the monthly CBaR that becomes yearly CBaR can be understood in their dynamics as short-term loans, this finding seems to corroborate the results of Bartram *et al.* (2015) who demonstrated the importance of risk optimisation for company results when they take out loans. Table II shows the potential effects on performance of the two investment projects. In Figure 3, these effects are shown for the zero drift foreign exchange rates.

An evaluation of the final impacts of each project reveals that even though expected returns are slightly greater for the expansion project, the risk metrics are better (less risky) for the innovation project. The main effect of the technological innovation project over the company risk is a distinctly better diversification of risks and therefore a greater stability for the company's cash balance. The cash balance net risk reduction is 122 per cent higher for the innovation project than for the expansion one. There are various reasons for this: first, while the expansion project retains the same pattern of exposure and risk factors as the current company business, the innovation project has more diversified exposure due to the new supplies and products; second, the lower cost of the new raw material does not increase profit, because of the final product price policies, however, it reduces the effect of the time delay between inflows and outflows; third, the lower volatility of the new reference price also helps to reduce risk.

According to Paquin *et al.* (2016), "no risk reduction can ever be expected" from adding a new project as this will normally pose new risks to the company. However, the authors work with absolute risk. Our research also found an increase in absolute risk (from 30 to 36 in expansion project and 32 in innovation project – million reals), while our metrics are based on relative risk, which can be reduced as shown above.

Conclusions

This paper presents a method that allows the evaluation of the financial risk associated to the impacts of new projects in a petrochemical commodity industry. This method highlights the gains of innovative projects which, through the implementation of new technologies, can change the financial risk exposure of a commodity-intensive company (e.g. by allowing the use of new resources or by generating new products). The method was applied to a hypothetical case study based on a real situation, which demonstrated the benefits of using the method as a complement to usual analysis methods.

The use of the stochastic method from two perspectives, the accrual basis and the cash basis, enabled the identification and mitigation of risks that would not have been identified by other traditional methods. In the case study, although the hedged Innovative project presented only 7 per cent more over the hedged expansion project in the resulting company's earnings risk, it was possible to measure a substantive difference of 46 per cent

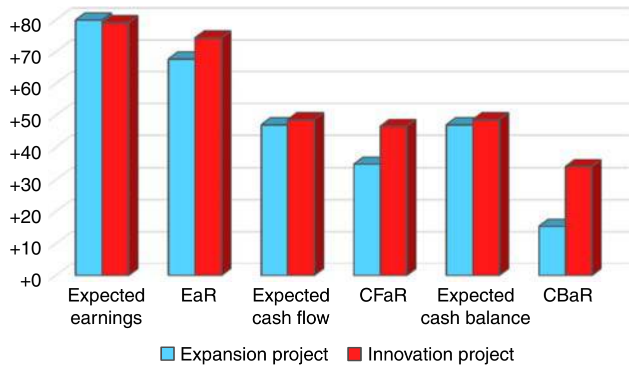

Figure 3.
Project impact on company results and exposure (MM BRL)

in the cash balance risk. This financial risk reduction difference was obtained by the diversification of risk and by using inputs with a softer price oscillation (a cheaper and less volatile price).

Another contribution of this paper is that it includes financing and hedging strategies in in project evaluation, including a model for commodity pricing. With the use of these combined factors, it was demonstrated in this case study that it was possible to achieve a 24 per cent improvement in earnings risk reduction, 26 per cent in cash flow risk reduction and 40 per cent in cash balance risk reduction when compared to plain project evaluation. These results can be achieved by the use of the GRG method for optimising relationships between the following variables: the volatility and correlations of commodity prices and foreign exchange rate; loan interest rates; production and inventory forecasts; and the delays between accrual basis results and cash basis results.

Both contributions enable a better evaluation of project impacts and of innovation benefits on companies' financial risk, providing a framework for smoothing expected cash flow and earnings. Measuring financial risk contributes to a rationale for the risk aversion commonly found in managers and companies in Brazil and Latin America. This, besides the actual risk reduction provided by this method, is an additional step in the process of overcoming barriers to the innovation process. The results are robust although there are opportunities for improvement, such as the use of econometric studies and price forecasting. Further research should also include the use of multi-stage optimisation methods that would enrich the evaluation by including the possibility of managers changing their decisions as new information arises over time.

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