[Inner endpaper]

HEC MONTRÉAL
École affiliée à l'Université de Montréal

The Effect of Interest Rate Hedging and Cash Flow in Risk Management of Non-financial Firms

par
Abolhasan Karamad

Mémoire présentée en vue de l'obtention du grade de maîtrise ès sciences (M.Sc.)
(économie financière appliquée)

April 2022

Résumé

Cette étude étudie l'effet de la couverture des taux d'intérêt dans la gestion des risques des entreprises non financières en examinant l'effet de la couverture des taux d'intérêt et des volatilités des flux de trésorerie en plus d'autres caractéristiques de l'entreprise et des caractéristiques de l'environnement économique sur la valeur, le risque et la performance comptable de l'entreprise. À cette fin, nous avons construit un échantillon de 139 activités de couverture des taux d'intérêt des producteurs de pétrole américains au cours des trimestres de 13 ans à partir des résultats de 1998 à 2010 en utilisant 4 511 observations trimestrielles dans notre échantillon. Nous étudions à la fois l'effet moyen et l'effet marginal de la couverture IR sur la valeur de l'entreprise, le risque et la performance comptable des producteurs de pétrole de notre échantillon.

Selon la littérature et les travaux empiriques antérieurs, les analyses menées dans le domaine de la gestion financière et des risques des entreprises sont exposées à l'hétérogénéité, à l'autosélection, à l'endogénéité et à d'autres problèmes d'estimation. De plus, l'effet marginal du traitement sur la valeur et le risque de l'entreprise pourrait varier d'une entreprise à l'autre en raison de différences non observées entre elles au-delà des variables de contrôle. Ainsi, nous avons utilisé les changements de l'indice Kilian comme instrument pour les décisions de couverture des taux d'intérêt afin de surmonter les problèmes d'endogénéité et la méthode paramétrique du modèle d'hétérogénéité essentielle comme méthodologie économétrique plus robuste qui contrôle le biais lié à la sélection sur les inobservables et l'auto-sélection dans l'estimation des effets marginaux du traitement.

En ce qui concerne la volatilité des flux de trésorerie, notre étude montre que la volatilité des flux de trésorerie diminue la valeur de l'entreprise des producteurs de pétrole et augmente leur risque idiosyncrasique et leur risque total, mais les entreprises qui font de la couverture IR pourraient bénéficier de la volatilité des flux de trésorerie et augmenter leur rendement des capitaux propres.

En outre, selon nos graphiques des effets marginaux du traitement, nous constatons que les producteurs de pétrole avec des scores de propension plus élevés pour l'utilisation de la couverture IR ont tendance à avoir une valeur d'entreprise marginale plus élevée et des risques marginaux systématiques et de crash plus faibles. Ces producteurs de pétrole avec des scores de propension plus élevés qui font face à une résistance inobservable plus faible à la couverture des taux d'intérêt ont également un effet de traitement moyen positif pour la valeur de l'entreprise et un effet de traitement moyen négatif pour le risque systématique et le risque de crash des producteurs de pétrole couverts en taux d'intérêt et vice versa pour les non - couvertures. Mais la principale considération concernant les effets marginaux estimés du traitement sur les éléments non observables et l'effet moyen du traitement est que tous les effets mentionnés dans ce paragraphe ne sont pas statistiquement significatifs. Ainsi, les dérivés de taux d'intérêt que les producteurs de pétrole déclarent comme des instruments de couverture IR n'ont pas d'effet statistiquement significatif sur la valeur et le risque des producteurs de pétrole. En d'autres termes, il n'existe aucune preuve statistiquement significative sur l'utilisation des dérivés de taux d'intérêt comme instrument de couverture approprié à des fins de gestion des risques qui pourrait affecter la valeur et le risque de l'entreprise.

Enfin, le MTE juste estimé sur les éléments non observables pour le ROE est statistiquement significatif pour les producteurs de pétrole ayant des scores de propension plus élevés à faire de la couverture, ce qui montre que la performance comptable des producteurs de pétrole est positivement affectée par la couverture IR. Ce résultat important est l'un des résultats de l'analyse MTE où de tels effets n'apparaissent pas dans l'analyse ATE standard et indique la nécessité d'utiliser l'analyse MTE.

Mots clés: Gestion des risques d'entreprise, valeur ajoutée, réduction des risques, couverture de taux d'intérêt, volatilité des flux de trésorerie, producteurs de pétrole, effet de traitement marginal, effet de traitement moyen, modèle d'hétérogénéité essentielle, casualité.

Méthodes de recherche: Variable instrumentale, Modèle d'hétérogénéité essentielle.

Abstract

In order to find out how interest rate hedging affects the risk management strategies of non-financial firms, we examine the effects of interest rate hedging, cash flow volatilities, other firm characteristics, and economic environment features on the value, risk, and accounting performance of these firms. For this purpose, we use the quarterly data associated with a sample of 139 oil-producing firms in the U.S. during 13 years from 1998 to 2010, which results in 4511 firm-quarter observations. We study both the average and marginal effects of interest rate hedging on the value, risk, and accounting performance of the U.S. oil producers in our sample.

According to the literature, empirical studies on firms' risk management strategies deal with heterogeneity, self-selection, endogeneity, and other problems. Moreover, the marginal treatment effect of interest rate hedging on the value and risk can vary across the firms due to their unobserved differences, i.e., the differences other than the ones in the control variables. In this respect, in order to overcome the endogeneity problem, we use changes in the Killian index as an instrument for the interest rate hedging decisions. In order to control for self-selection bias and also the bias which arises from selecting unobservables in estimating marginal treatment effects (MTEs), we use the parametric method of essential heterogeneity models as a more robust econometric methodology.

Our study shows that as the cash flow volatility of an oil producer increases, it's idiosyncratic and totals risks increase and its value decreases. However, those firms involved in interest rate hedging activities can benefit from cash flow volatility and increase their ROE.

Furthermore, according to our MTE plots, we find out that oil producers with higher propensity scores for interest rate hedging activities tend to have higher marginal value and lower marginal systematic and crash risks. The oil producers with higher propensity scores mean they experience lower unobservable resistance against interest rate hedging also have a positive average treatment effect on the firm value and negative average treatment effect on the systematic and crash risk in the treated group (IR-hedged) and vice versa for non-hedgers (untreated group). But the most important consideration about the estimated MTEs over unobservables and ATE (ATT and ATUT) is that all the aforementioned effects are not statistically significant at the level of 10%. Thus, interest rate derivatives that oil producers report as IR-hedging instruments do not have any statistically significant effect on oil producers' value and risk. In other words, there is no evidence to confirm interest rate derivatives as appropriate hedging instruments for risk management purposes affecting nonfinancial firms' value and risk.

Lastly, just estimated MTE over unobservables for ROE is statistically significant for oil producers with higher propensity scores to do hedging, showing that oil producers' accounting performance is positively affected by IR hedging. This important result is one of the outcomes of MTE analysis where such effects don't appear in standard ATE analysis and indicates the necessity of using MTE analysis.

Keywords: Corporate risk management, value adding, risk reduction, interest rate hedging, cash flow volatility, oil producers, marginal treatment effect, average treatment effect, essential heterogeneity model, causality.

Research methods: Instrumental variable, Essential heterogeneity model.

Table of contents

List of tables

List of figures

List of acronyms

Abbreviation	*explanation*
ATE	Average Treatment Effect
ATT	Average treatment Effect on Treated group
ATUT	Average treatment Effect on UnTreated group
IR	Interest rate
IR-hedging	Interest rate hedging
LATE	Local Average Treatment Effect
MPRTE	Marginal Policy-Relevant Treatment Effect
MTE	Marginal Treatment Effect
PRTE	Policy-Relevant Treatment Effect

For all people who sacrificed all for freedom, dignity and humanity; where ever on planet and any time in history.

Acknowledgements

I give special thanks to my supervisor, Professor Georges Dionne and Professor Mohamed Mnasri for their help, time and comprehensive support. The completion of this project would never have been possible without them. I also appreciate my parents who supported me during the entire project. Lastly, I want to thank my wife Farzaneh for her encouragements and dedications on taking more responsibilities to give me more time for working on this essay.

Introduction

The purpose of this study is to analyze the effects of interest rate derivatives, as hedging instruments, on the value and risk of a sample of US oil producers, as nonfinancial firms.

As Modigliani and Miller (1958) argue, in a frictionless world, there is no need for risk management activities because they cannot enhance the firm value. However, more recent studies show that risk management can, directly and indirectly, impact the firm value. Nowadays, risk management using derivatives has become one of the main financial activities that even non-financial firms consider to protect themselves in an imperfect world. According to KPMG (2013) which has conducted a survey all over the world, 81 percent of executives define risk management as always or occasionally essential for adding value to the overall business, and 86 percent to some degree count risk management considerations. Moreover, 66 percent of business executives expect an increase in investments associated with risk management activities over the next three years.

Given the complexity of the risks that companies face, the management of those risks is a high priority. According to the most recent volume of the reports which are annually published by the Bank of International Settlements (BIS 2021), notional amounts of using over-the-counter foreign exchange (FX) and interest rate (IR) derivatives by non-financial entities continuously has increased over the last 5 years by almost 10 percent and the amount of interest rate instruments are now above US$ 262 trillion (notional value) for financial and non-financial firms.

As a matter of fact, using derivatives as hedging instruments can be an appropriate way for reducing the risks of a firm and add to its value. Several empirical studies examine the effects of non-financial firms' hedging activities on their values and risks, that we will study some of them in the literature review; however, the effects of IR-hedging can be somehow ambiguous since IR derivatives, if used as risk management instruments, can reduce the firm's risks and increase its value, but if used by the managers for speculation, can increase the firm's risk and decrease its value. Thus, on one hand, the findings on the value implications of risk management strategies are somehow inconclusive, and on the other hand, we face methodological problems related to the endogeneity of derivatives and firm decisions that traditionally affect analyzing the financial issues of the firm. In order to overcome the methodological problems such as sample selection, sample size, and the existence of other potential hedging mechanisms (e.g., operational hedge), we will use one of the most recent models named the essential heterogeneity model.

For analyzing the effect of IR hedging (interest rate derivatives) on the value and risks of oil-producing firms, we consider Tobin's q as a measure of the firm value and the idiosyncratic risk, systematic risk, total risk, oil beta, and crash risk as the measures of the firm risks. We also analyze the effect of interest rate hedging on oil producers' return on equity (ROE) as a measure of firms' accounting performance.

In this essay, first, we review the literature and analyze the empirical works related to our subject to find out more about the best model and methodology we can use and the results we predict for our model in chapter 1. In chapter 2, we explain the variables which we use to study the effects of IR-hedging on oil producers' value and risk, our sample and data extraction and the way we gather the data. In chapter 3, we introduce our model and its capabilities in dealing with technical problems and also introduce some mathematical, statistical, and financial approaches to the selected model. In chapter 4, we present our intermediate and final results and analyze them. Finally, we conclude based on the analyzed results.

Chapter 1
Literature

As we mentioned in introduction, financial hedging plays a central role in risk management. There are a lot of works regarding the real effect of hedging on firm's performance in literature, theories, and empirical works. In this chapter we go to have a survey on the main important theories in the field of hedging effect on firm performance and the factors which motivate a firm to do hedging and then survey some empirical works that investigate firm performance changes by hedging, using derivatives, interest rate hedging, and hedging in oil and gas industry. The ambiguous effect of hedging could become more obvious after studying this works.

1.1 Theoretical Review

Modigliani and Miller (1958)'s theorem implies that under the assumption of a perfect capital market, corporate hedging is irrelevant for firm value. In a frictionless market, individual investors can hedge on their own (instead of the company hedging on their behalf), because they have access to the same information and the same hedging instruments. In such a situation, individuals can learn from prices. So, in that sense, firms try to invest in riskier opportunities which lead to more returns. If the assumptions of a perfect capital market are violated, which is inevitable in the real world and more likely to happen in comparison with perfect markets assumption, there are several channels through which hedging at the firm level may affect shareholder value and create a hedging premium.

We can say that reduction of firms facing risks and consequently increasing firm value (directly or indirectly) is the main important role of risk management. The invariance result of a perfect market stands in sharp contrast to the prominence of risk management in practice, and the rapid growth in financial innovation (Miller, 1986; Tufano, 2003).

In such an imperfect market, cash flow volatility is costly due to financial distress, convex tax functions (Smith and Stulz, 1985), external financing (Froot et al., 1993), or information asymmetry between the firm and its shareholders (DeMarzo and Duffie, 1991). As hedging is an instrument to improve cash flow stability, it may reduce the costs of market friction and thereby positively affect shareholder value.

According to literature the main reasons for financial markets imperfection comes from 5 predominant factors which are Taxes, Cost of Default, Agency problem, Problems of Governing the firm, and Risk Behavior of Managers. (Dionne and Mnasri 2018). With this explanation, the two latter ones are more common in firms that suffer from lack or insufficient regulations.

1.1.1 Tax Payments

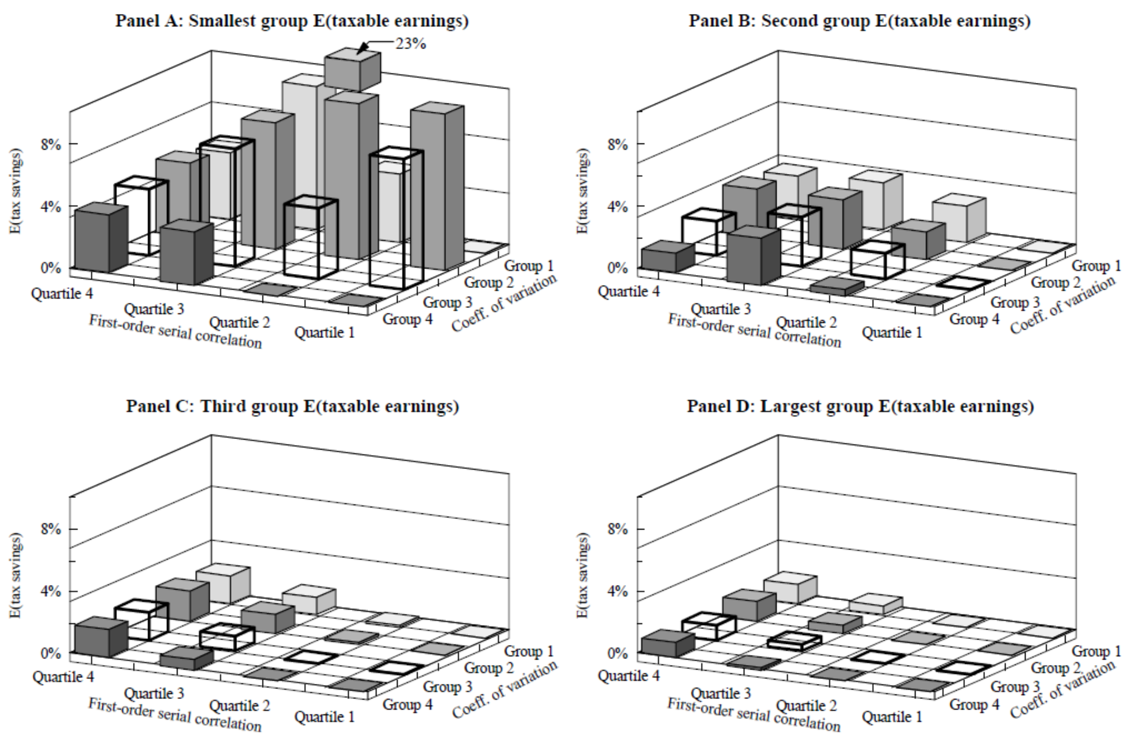
There are two tax incentives for corporations to hedge. The first is to increase debt capacity and interest tax deductions, and the second is a reduction of expected tax liability if the tax function is convex. (Graham and Rogers,2002).

For corporations facing tax-function convexity, hedging lowers expected tax liabilities, thereby providing an incentive to hedge. Graham and Smith (1999) used methods to investigate convexity induced by tax-code provisions. On average, the tax function is convex (although in approximately 25 percent of cases it is concave). Carrybacks and carryforwards increase the range of income with incentives to hedge; other tax-code provisions have minor impacts. Among firms facing convex tax functions, average tax savings from a five percent reduction in the volatility of taxable income are about 5.4 percent of expected tax liabilities; in extreme cases, these savings exceed 40 percent. (Graham and Smith,1999).

When firms are facing an always convex tax function they will hedge more because lowering the firm value and income in the next period will result in fewer tax rates (convex function has an increasing slope, so if we go back on this kind of function the slope which here is the tax rate will decrease) and consequently, the firm will benefit of such kind of hedging because of reduction in tax deductions.

According to Graham and Smith's work as it is illustrated by Figure 1.1 tax saving which is a result of hedging activities, is affected by firms' characteristics like expected earnings, absolute coefficient of variation, and first-order serial correlation. For this survey, Graham and Smith have used historical data from COMPUSTAT to calculate the coefficient for each firm-year observation during 1980-1994. The data represent 84,200 firm-year observations. Tax savings expressed as a percentage of the sum of the expected tax bill in year t plus the present value of the benefit from reducing past and future tax bills due to the extended provisions of the tax code, based on a three percent reduction in the volatility of taxable earnings.

Figure 1.1: Tax saving from hedging conditional on earning characteristics



Source: Graham and Smith 1999

Characteristics grouped as A) expected value: earnings less than zero (which contains approximately 32 percent of their sample population), earnings in the progressive region of the statutory tax schedule (earning between zero and $100,000 in most years of survey; approximately two percent of the sample population), and even ones which left between two groups; B) absolute coefficient of variation: subdivides firms into quartiles based on the absolute coefficient of variation for earnings. For positive earnings firms, expected tax savings rise almost uniformly with the coefficient of variation; the higher the volatility of the firm’s taxable earnings, the greater the reduction in expected taxes. The same general pattern holds for loss firms, although it is not monotonic; C) correlation coefficient: grouped by the serial correlation coefficient of taxable earnings. Group 1 contains all firms with negative estimated serial correlation coefficients (approximately one percent of the sample), Groups 2 through 4 contain the remaining firms. The tax savings from hedging are greater for firms with lower serial correlation coefficients. These are the firms that are more likely to alternate between profits and losses.

Between four earning groups, the largest percentage tax savings occur in Groups 1 and 2 which are nearer the kink, or statutory-progressive region, of the tax schedule. This is a reason for the effect of change in tax giving and going above a hurdle on the tax receiving due to hedging.

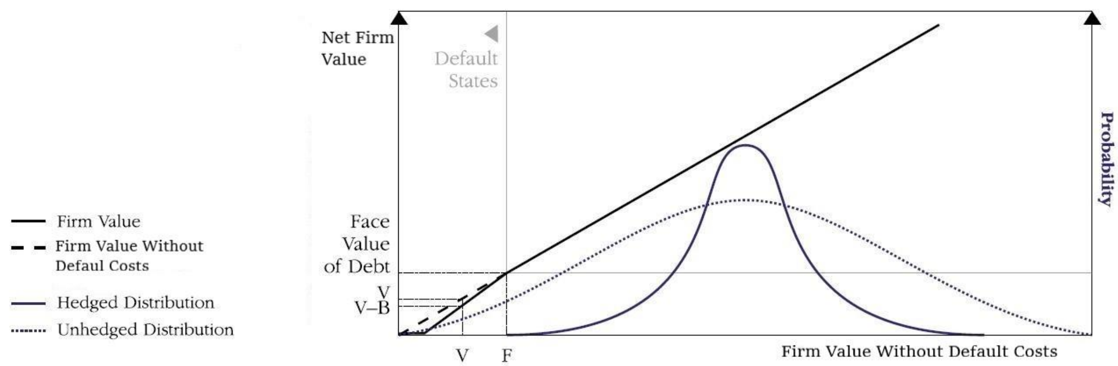
When it comes to the absolute correlation coefficient, the higher the volatility of the firm's taxable earnings, the greater the reduction in expected taxes. Finally, the tax savings from hedging are greater for firms with lower serial correlation coefficients.

1.1.2 Cost of Default

Default costs are something beyond bankruptcy costs which are more reflected in books and audition and accounting offices. In other words, default cost goes beyond the obvious direct costs which are visible in the case of default (or going under). It may include not only common costs associated with bankruptcy but also some direct costs like lawyer costs, costs of reorganization, consultation costs, higher debt costs, and even more indirect costs like reputation loss, losing opportunities, distracting managers from more profitable activities too. Default costs are related to distress costs. Distress cost refers to the expense that a firm in financial distress faces beyond the cost of doing business, such as a higher cost of capital. Companies in distress tend to have a harder time meeting their financial obligations, which translates to a higher probability of default. Distress costs may extend to the need to sell assets quickly and at a loss to cover immediate needs.

The default cost is one of the reasons which the market perfection assumption mentioned in Modigliani and Miller's model will be violated. Because of default cost, risk management activities (and particularly hedging activities) could have an effect on firm value. Through logical risk management activities, the manager by considering two main concerns, tries to increase firm value. These two are the cost of using risk management instruments (for instance using hedging instruments like interest rate hedging by derivatives) and the cost of default to find an optimal way leads to the lowest costs for the firm.

Figure 1.2: Firm value and distribution with and without default cost conditional on hedging



Source: Stulz 1996

Stulz showed that the effects of risk management on default costs and firm value are illustrated in Figure 1.2. In the case shown in the figure, hedging is assumed to reduce the volatility of cash flow and firm value to the degree that default is no longer possible. By eliminating the possibility of default and financial distresses, risk management increases the value of the firm's equity by an amount roughly equal to DC (default costs) multiplied by the probability of default if the firm remains unhedged (PDC). For example, if the market value of the firm's equity is $50 million, default costs are expected to run $5 million (or 10% of current firm value), and the probability of default in the absence of hedging is 5%. In this case, risk management can be seen as increasing the current value of the firm's equity by $250,000 (5% * $5 million), or 0.5%. (It is the contribution of risk management to firm value when the company is healthy; if cash flow and value should decline sharply from current levels, the value added by risk management increases in absolute dollars, and even more on a percentage-of-value basis.)

As a company becomes weaker financially, it becomes more difficult for it to raise funds. At some point, the cost of outside fundings and debt costs, if available at all, may become so great that management chooses to pass up profitable investments. This "underinvestment problem" experienced by companies when facing the prospect of default[1], represents an important cost of financial distress. According to the figure 1.2, risk management succeeds in reducing the perceived probability of financial distress, default cost, and the costs associated with underinvestment, which could result in an increase in the current market value of the firm.

1.1.3 Capital Structure and Risk-Taking

Another important issue that violates the perfect market hypothesis is capital structure. As studied in the previous part, using appropriate risk management instruments will decrease default probability and as a result, the debt cost could fall for the firm, firm can borrow easier at lower premiums and interest rates because it faces lower financial distresses and probability of default. So, the debt capacity could increase and it will change leverage (increase it) and capital structure too. As a matter of fact, firms can borrow more and finance their new investment opportunities beyond cash flow problems. Using more investment opportunities could also have a positive effect on firm value. In other words, using risk management instruments like hedging will lead to risk premium reduction and it can create new investment opportunities financed by debt (Dionne and Triki, 2013).

Moreover, there is a reverse effect of capital structure on risk management contrary to the effect of risk management mentioned earlier on the capital structure of the firm.

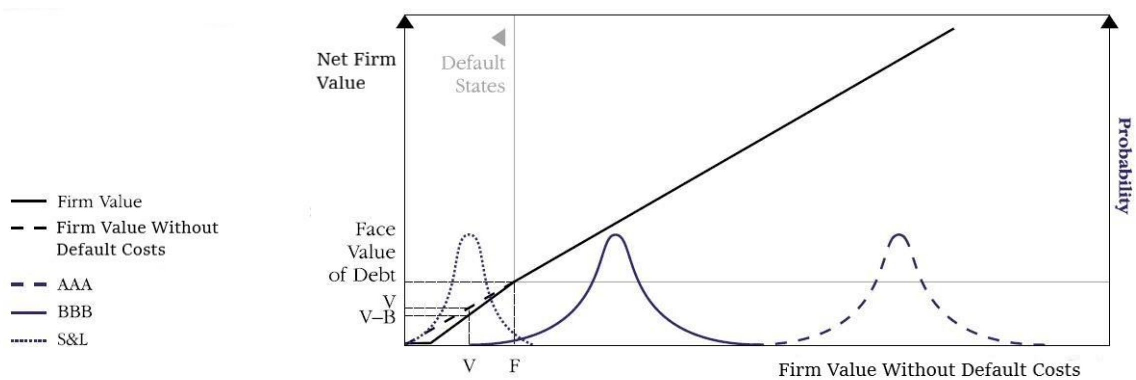
Risk management could be presumed as a substitute for equity capital or alternatively, as a technique that allows management to substitute debt for equity. So, because of these two-way effects and some causal effects which could be assumed to be present in studying these two subjects, a company's decisions to hedge financial risks or to bear part of such

[1] . This condition of higher cost of debt and going to underinvestment problem, even could be experienced by the firms out of default conditions which just have a sharp fall in their earnings and liquidity and are on status of insolvency.

risks through selective hedging should be made jointly with the corporate capital structure decision.

Slutz as is illustrated in Figure 1.3 shows the interdependence between risk management and capital structure, by assuming three kinds of companies. Company AAA has little debt and a very high firm rating. The probability of default is essentially zero for this company because its distribution is far from the default state and its distribution left or lower tail of potential outcomes never reaches the range where low value begins to impose financial distress costs on the firm. Based on the literature, there is no reason for this company to hedge its financial exposures. And, should investment opportunities arise, AAA will likely be able to raise funds on its regular basis and funds its investment projects through its existing resources, even if it faces liquidity problems and needs external funding through new equity issuing or more debt requesting. Such a company by the benefits of its comparative advantages provided by management's specialized information in a certain market can have the best results in financial markets.

Figure 1.3: Hedging and Firm value conditional on Firms' Capital Structure



Source: Stulz 1996

For the company in the middle of firms' distribution of value, BBB has a lower credit rating, and there is a significant probability that the firm could face distress. This firm faces the condition which was shown in Figure 1.2 as the common example of the firm which its value will be affected by hedging and risk management. This firm should probably eliminate the probability of encountering financial distress through risk management. For Company BBB, with just partial opportunities of using market inefficiencies, hedging could help the company for making the most of this imperfection. In company BBB's case, using hedging instruments could reduce financial distress costs and add value to the firm. Consequently, managers are not expected to do speculation or invest in every opportunity for increasing their reputation in firm, because such activities will increase volatility and impose more financial distress costs and the probability of default on firms.

Finally, the "S&L." company is almost trapped in the default state. Reducing risk once the firm is in distress, is not in the interest of shareholders because, in the case of staying in distress and eventually defaults, shareholders will end up with near-worthless shares which lost their more bets and return due to fluctuation as the volatility of the firm decreases by hedging activities. In these circumstances, a management intent on maximizing shareholder value not only accepts the volatility but also will seek even more. Such managers will take bets even if they believe markets are efficient because introducing new sources of volatility raises the probability of the "upper-tail" outcomes that are capable of rescuing the firm from financial distress or at least giving more return in short term to the shareholders.

As it was illustrated in figure 1.3 in the case of company AAA, firms that have a lot of equity capital can make new investments even without doing risk management hedging and considering financial distresses. So, these firms are not expected to hedge lot and aggressively, especially when using risk management instruments is costly and shareholders don't want it at the time.

But the incentive of changing the capital structure and increasing their current leverage in the case of being overwhelmed by capital or equity. In other words, although risk management may not be useful to them directly by avoiding financial distress costs or default probability and its associated costs, consideration of current leverage ratios might motivate them to use risk management, hedge more, decrease debt cost, and increase leverage. Furthermore, debt financing has tax advantage over equity financing, and moreover, increasing leverage also strengthens management incentives to improve efficiency and add value.

On the other hand, the substitution of debt for equity also allows for a greater concentration of equity ownership and reduces overinvestment problems. So, reducing agency problems are one of the main important incentives of taking risk management and hedging activities into consideration to protect the firm value and avoid its malfunctioning.

1.1.4 Agency Problems

Agency problems address the conflicts between shareholders and managers and on the other side between managers (plus shareholders) and debtholders. Sometimes conflicts between agent and principal may result in decisions that affect firm value and deprive the principal (which is shareholder for the first group and debtholder for the second agent-principal group) of its wealth and benefits.

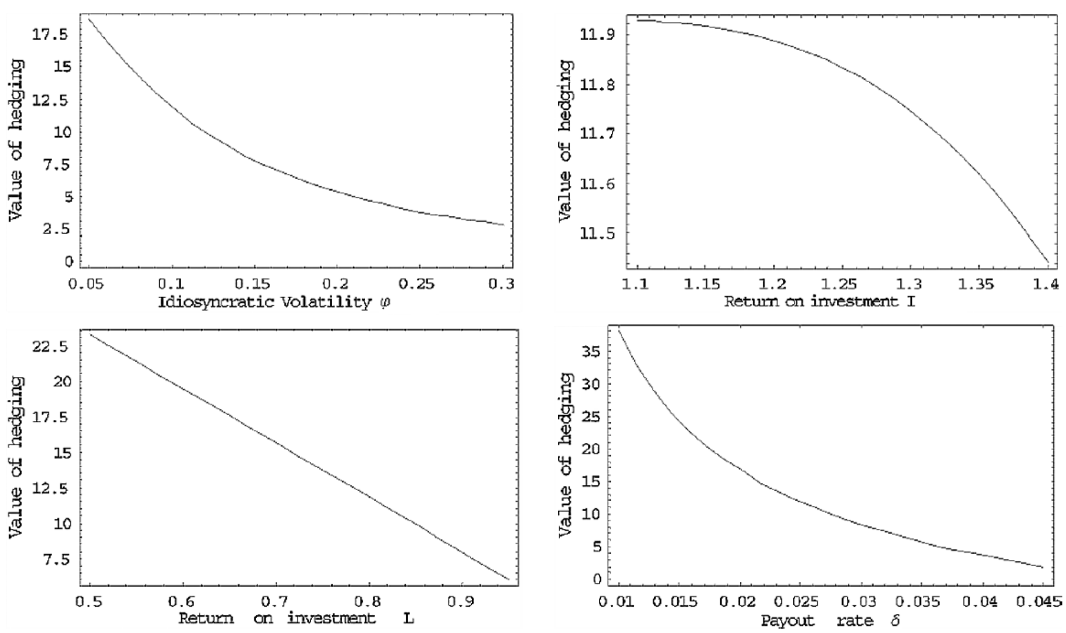
According to Morellec and Smith (2007), when a firm faces free cash flows which are available for managers, even after all positive NPV projects have been invested, managers would start to invest on even minus NPV investment projects for empire building purposes or make the most of free resources. It will obviously reduce firm value and has detrimental effect on shareholders' benefits. We can consider this as a shareholder-manager conflict that could tackle by more debt financing by the firm. Debt financing will reduce this overinvestment problem and agency costs associated with that but as we know it will result in other problems of investing by debt. This solution, will increase debt costs for the firm, increase default probability and financial distress cost will rise. Moreover, more debt will reduce the firm's ability to invest in all the investment opportunities face and may cause underinvestment problems as managers will become more cautious while they are facing more debts now.

As it was shown, reducing the overinvestment problem by more debts could result in an underinvestment problem, but using hedging instruments and benefiting from risk management tricks will overcome the overinvestment problem, solve agency conflict and reduce its costs, in the case of free cash flows, without resulting in underinvestment problem and depriving the firm of potential perks of good projects.

In particular, a firm's risk management strategy should reflect not only the underinvestment costs associated with stockholder-debtholder conflicts but also the overinvestment costs due to manager-stockholder conflicts. In another word, on one hand, underinvestment incentives due to stockholder-debtholder conflicts may lead firms with more growth opportunities (higher market-to-book ratios) to hedge more (Bessembinder,1991) and on the other hand, firms that derive more of their value from assets in place (lower market-to-book ratios), although having lower costs of underinvestment, generally display larger costs of overinvestment, may be more likely to hedge to control these overinvestment incentives as was shown in Aretz and Bartram(2010).

Figure 1.4 shows that the value of hedging evolves as input parameter values change when the value-maximizing amount of debt is floated. So, the benefits of risk management increase as the free cash flow problem becomes more severe (decrease in L and δ) or as the hedging instruments become more effective (decrease in ϕ).

Figure 1.4: Value of hedging as a function of input parameter values



Source: Morellec and Smith 2007

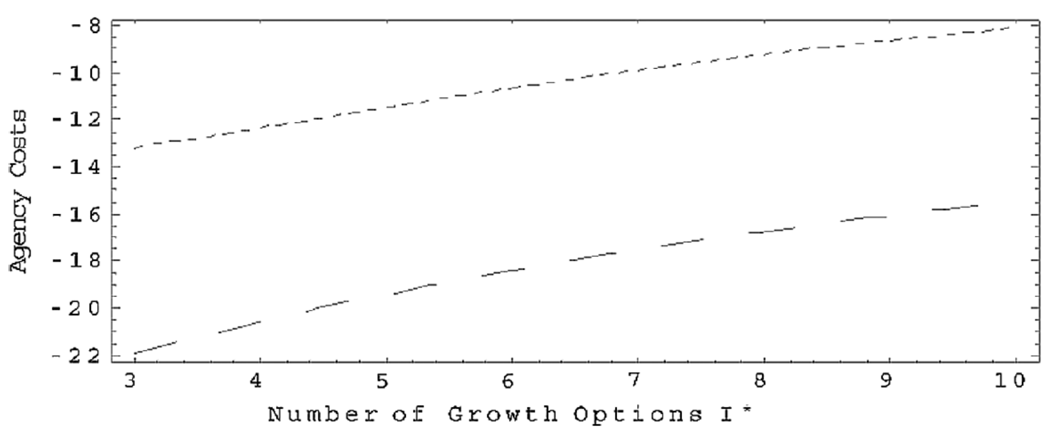
1.1.5 Investment Financing

Using risk management, as was said before, a firm can overcome agency problems and overinvestment and underinvestment problems by smoothing cash flow fluctuations. Morellec and Smith (2007) showed in their model that, the impact of financial decisions on firm value can be related to changes in the firm's investment policies. Specifically, by reducing cash flow volatility, risk management reduces the probability of low cash flows as well as the probability of high cash flows. As a result, there could be more resources for financing investment opportunities by reduction of low cash flows and having more stable cash flow availability. When the external financing resources are more costly in comparison with internal resources, doing hedging to reduce the fluctuations of firm's future cash flow will give the opportunity to firms to have more chance to use their internal resources to finance more investment projects as using external financing could be more costly or even sometimes impossible. (Myers and Majluf(1984))

To illustrate the impact of risk management on investment policy Figure 1.5 plots agency costs in the base case environment as the number of growth options. The long-dashed line represents the value of a levered firm without hedging and the short-dashed line represents the value of a levered firm with hedging. According to the graph, hedging should be particularly valuable for firms that have narrow access to external financings.

As a matter of fact, hedging will increase investment financing by using more growth options to reduce agency costs.

Figure 1.5: Agency costs in the base case environment



Source: Morellec and Smith 2007 and Froot, Scharfstein, and Stein (1993)

1.1.6 Managers' risk aversion

To avoid more conflicts between shareholders and managers incentives, one of the solutions is to compensate managers as a function of the firm value for more alignment of managers incentives with shareholders ones. Frequently observed managers provisional compensations contract leads to managers total annual compensation as an increasing function of firm value. (Smith and Stulz, 1985). As a direct result, the firm's payoff distribution will give the utility of managers and if the manager is more risk-averse, she will be more interested in hedging more and in the case of being more risk-taker will be more interested in using fewer hedge instruments to try her chance on more volatile returns on firm's activities.

Moreover, the utility function of the end of the period of the firm value will be very important in this sense too. For example, for a manager with stable risk aversion, more concave utility functions at the end of the period will entice managers to hedge more (even completely hedging) in comparison with the condition that the manager has convex utility function at the end of the period value of the firm.

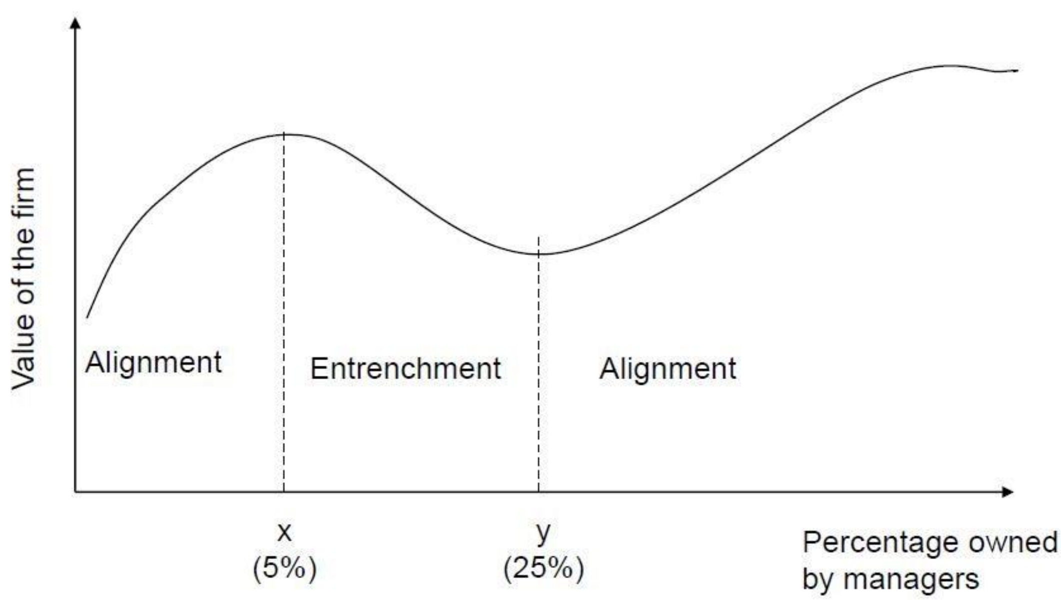
The most important thing is that although the fact that when managers are compensated by the firm value, more risk-averse managers will avoid more risky investments and use more hedging instruments, the magnitude of this usage depends on the expected rate of return on all financial assets. When the expected return increase, managers will hedge less, because there will be a kind of trade-off between risk aversion and expected return.

1.1.7 Company governance combination and compensation

As it was studied in the previous part, for more alignment in incentives of managers and shareholders, sometimes shareholders design contracts that depend on the managers' compensations with firm value. In some cases, this kind of firm-value-dependent compensation will be done through compensating managers by a proportion of corporations. So, managers own a part of a company to be benefited from firm value increase as shareholders act in their motivations. If directors own and manage the firm, there still could be a possibility of acting against the interest of outside shareholders. Even if the larger part of the firm they own, there is some incentive for them to extort benefits they have because of the more power they gain through more governance and ownership rights. On the other hand, more ownership and governance on the firm could give them a stronger incentive to maximize value (act in the interest of everyone and other shareholders).

There are pieces of evidence that both effects of gaining ownership of a firm will be experienced in a firm. By gaining a proportion of firm (firm stock as a compensation) managers will act in the way of the entrenchment and alignment depending on the proportion they own. (Morck, Shleifer, et Vishny (1988))

Figure 1.6: Firm value as a function of the proportion of firm stock owned by managers

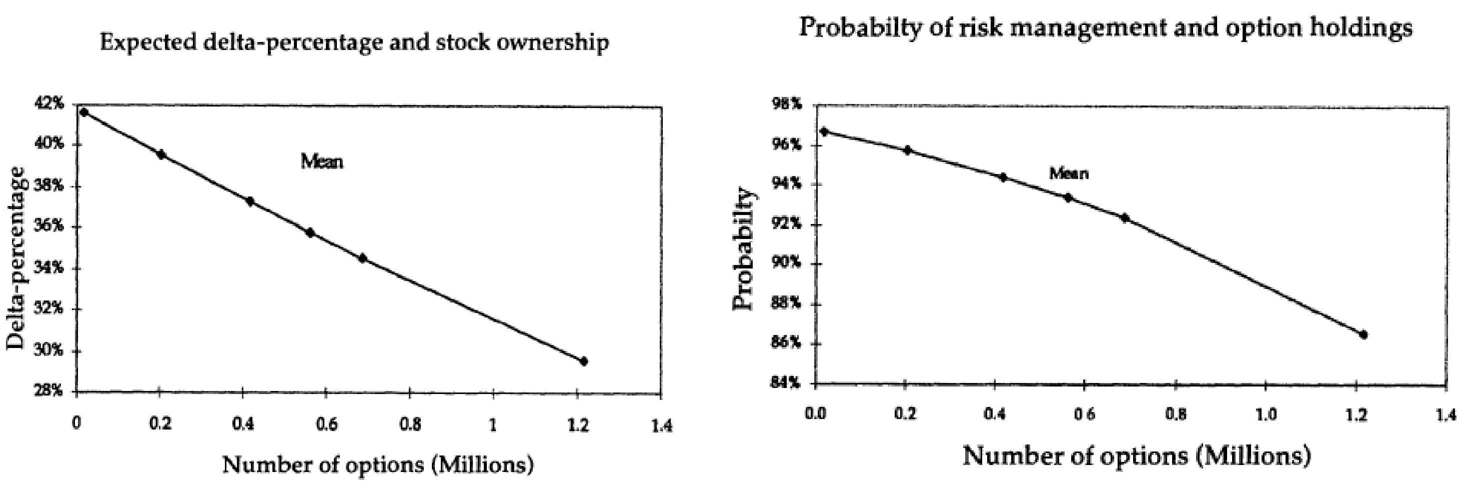


Source: Morck, Shleifer, et Vishny(1988)

Figure 1.6 Show that entrenchment and alignment effects are both present in the case of stock-compensation of managers. When the managers are compensated by less than 5 percent of the firm's stocks (managers own less than 5 percent of the firm) they will act more in the interest of all shareholders. By increasing managers' share of the firm, their power will increase too and they will act in their favor, against the interest of outside shareholders and extort more from the firm will result in a decrease in firms value which is calculated by "Tobin's Q" in this survey. As the managers' percentage of ownership exceeds 25 percent, the alignment of the managers' interest with firm value and other shareholders will overwhelm their extortion and the firm value will increase again. So, the effect of compensating managers by firm shares does not always increase the firm value and reduce the conflicts obviously, and managers are not more interested in using hedging instruments. We can say just when the managers own less than 5 percent or more than 25 percent of the firm's share, they could have more incentives to use hedging and risk management to increase firm value.

On the other hand, compensating managers with stock options could result in a lower tendency to use risk management and hedging. Tufano (1996) showed in the gold mining industry that firms whose management teams hold more options and hence face greater convexity in payoffs tend to manage less gold price risk and less hedging.

Figure 1.7: Risk management as a function of the number of options held by managers



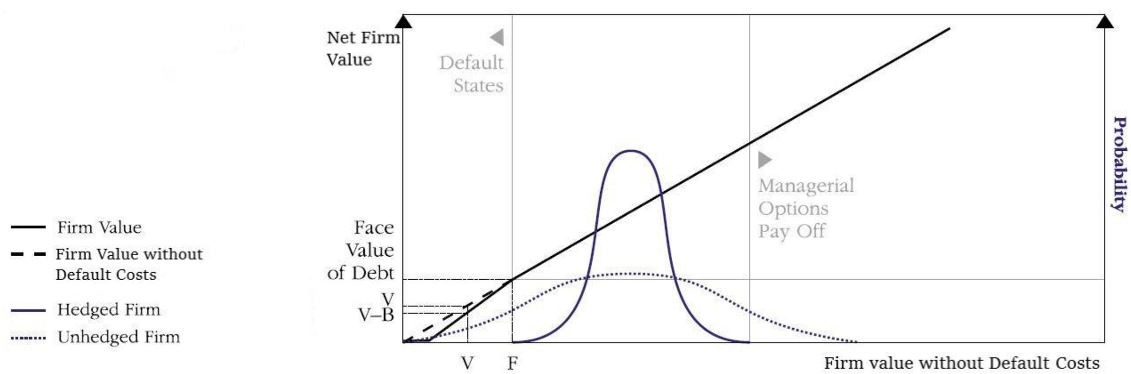
Source: Tufano 1996

Figure 1.7 illustrates the predicted level of risk management and the predicted probability of the firm entering into some risk management as a function of the number of options held by officers and directors. Graphs evaluate probabilities at the means of all of the other reported variables and different levels of managerial stock option holdings. The left graph shows the predicted level of risk management (delta-percentage) as a function of the level of managerial options holdings (conditional on the firm entering into some risk management.) The right graph shows the probability that the firm will enter into some risk management as a function of the level of holdings.

Tufano argues that managers with a significant fraction of their wealth tied up in their firms are likely to consider all sources of risk when setting their required rates of return. This could help explain the tendency of firms with heavy managerial equity ownership to hedge more of their gold price exposures. In such cases, the volatility of gold prices translates into the volatility of managers' wealth, and manager-owners concerned about such volatility may rationally choose to manage their exposures.

But when it comes to option compensation, conditions and the way which managers act will reverse. Stulz (1996) showed that managers which are compensated by stock options will hedge less because hedging will reduce volatility and their option return will reduce. Figure 8 shows how managers holding firm options, will be better compensated when they do less hedging by the chance of winning one side tail of return distribution. In another word, the right-hand side of distribution which is the one-sided payoff from stock options effectively rewards management for taking bets, increasing volatility, and doing less hedging. According to figure 1.8, the reduction in volatility from hedging makes management's options worthless, but if the firm does not hedge, there is a considerable probability that a large increase in gold prices will cause the options to pay off and go beyond the vertical line of managerial options payoff on the right tail of firm value distribution.

Figure 1.8: Managerial call option holding effect on hedging behavior



Source: Stulz 1996

There are other subsidiary effects of hedging like reduction of free cash flow volatility because particularly, for any given financing policy, implementing risk management strategies reduces the probability of default by reducing the volatility of cash flows.

1.1.8 Interest rate hedging

I can summarize the other incentives for risk management that entice firms to do more hedging, like more income, dividend payments, more assets, profitability, low liquidity, and other factors which as we will see in our model, we have to take their effect on hedging decisions when we are using them in our model. Now we can proceed to our main question of the essay how do hedging activities (which we are focusing here on interest rate hedging) affect firm value and firm risk exposure?

The motivations for risk management that were presented are likely to affect firm value and its risk too. These variables could be used as control variables in our model but as we will study in the methodology part using control variables and treatment (main independent variable: interest rate hedging) in a model for studying their effect on dependent variables (firm value and risk) cause endogeneity and some other technical problems which we have to tackle them. In the following, we will give some reviews on empirical studies on hedging effect on firm value and risk, interest rate hedging activities on nonfinancial firms, especially case of oil companies, etc. In the upcoming section, we study some empirical works in hedging and its effect on firm performance, model specifications, ways to overcome potential technical problems, and methodologies that could inspire us for this work.

1.2 Empirical studies review

There are a lot of works in the field of risk management and especially do hedging which surveys the effect of a different kind of hedging on firm value and risk, but the effect varies by the model they used and the methodology of their work. All positive, negative and non-significant effects of hedging on firm value and risk could be seen. In the following, we present some works on free cash flow and hedging effect on firm value, idiosyncratic and market risk of the firm and its accounting performance, then resume on empirical works on nonfinancial firms hedging and survey the special issue of the oil industry.

Altuntas et al (2017) examine Froot, Scharfstein, and Stein's (1993) model of the relationship between hedging, cash flows, and firm value. Specifically, by dividing the impact of derivatives hedging on firm value to direct and effect though the changes in cash flow volatility. Their sample contains 55 life insurers' data from 2002 till 2012 and found that hedging by derivatives and cash flow volatility is negatively related to firm value and conclude that hedging mitigates the negative value effect of cash flow volatility.

According to Hentschel and Kothari's (2001) work on 425 US firms for 3 years between 1991-1993, firms using financial derivatives could just have a small or even unobvious reduction in their risk in comparison with non-user ones. So, using financial derivatives has no obvious and strong effect on firms' risk reduction, and using derivatives by firms is not done completely as a hedging instrument that produces traditionally expected effects of hedging on firm value and risk.

Jin and Jorion (2006) use 119 US oil and gas firms' data for the period between 1998 to 2001 and find that hedging will reduce the sensitivity of firms' stock price to oil and gas prices but it hasn't a significant effect on firms' market value.

Seok et al (2020) did a two-stage analysis on 337 manufacturing firms in Korea from 2005 to 2014 to explain the determinants of hedging and conclude that more leveraged, larger, less profitable, and with more growth opportunities firms are likely to hedge through derivatives. In the second stage, results show that hedging with derivatives has a non-significant effect on firm value, where futures/forwards and swaps have a significant negative effect on firm value. Foreign currency (derivatives) hedging has a positive significant effect on firm value. On the other hand, hedging with derivatives increases market-based risk, but decreases accounting-based risk and assumes derivatives as an instrument to hedge operational volatility rather than market risk and this kind of risk reduction could not directly result in higher firm value.

Another study on the effect of agency problems on the impact of hedging by derivatives on firm value of US 1746 firms during 1991- 2000 time period by Fauver and Naranjo (2010) show that firms with greater agency and monitoring problems exhibit a negative significant effect of derivative usage on Tobin's Q.

Fairchild and Guney (2020) investigate the impact of corporate hedging activities on firm performance in UK corporations during 2005–2017 and noticed the ambiguous relationship between hedging and firm value which they specify could be because of a subtle combination of common agency problems. Results show that based on the way firms use hedging instruments the effect on firm value could change with firms' economical and managing conditions. Where FX hedger firms have a higher value compared to the non-hedgers, the effects of IR hedging on ROA and value are negative with significant and the impact of hedging CM risk on ROA (value) is negative (positive) with again significant differential effects. The effect is different completely for different contracts from future to swap and options.

So, according to the beforementioned work, the use of derivatives in risk management does not always add value. When the firm is involved in bad hedging, a reduction in shareholder value by doing hedging is expected. Managers are not always aligned with shareholders in their decision-making. So, some important determinants define how the impact of hedging on firm performance vary including agency problems, managers' caution, natural risk aversion, anxiety relating to financial distress, economic threats and punishments for bad decisions, and managerial risk management behaviors on whole.

On the other hand, in coincidence with theory, M. Bartram et al (2011) by using data of 6888 nonfinancial firms from 47 countries from 1998 till 2004, examine the effect of derivative use on firm risk and value. They consider the endogeneity problem and used matching users and nonusers based on their propensity to use derivatives and eliminate omitted variable bias in the model as a solution. Results show strong evidence that the use of financial derivatives reduces both total risk and systematic risk and increases firm value. Results are sensitive to endogeneity problems and omitted variable bias particularly when it comes to firm value.

Zamzamin et al (2021) examine the interactional effect between derivatives and managerial ownership on firm value by using 200 nonfinancial Malaysian firms using data for the period 2012–2017 through the generalized method of moments (GMM) model. The results show the positive influence of derivatives on firm value, and the negative significant effect of managerial ownership on firm value.

Mohammed and Knapkova (2016) examine the effect of risk management activities on firm performance for firms in the Prague stock market in 6 years from 2009 to 2014. The result reviled that there is a positive relationship between total risk management and company performance in companies that have invested higher levels of intellectual capital.

Pérez-Gonzalez and Yun (2013) show that active risk management policies lead to an increase in firm value. They also take into consideration the causal effect of hedging and to overcome endogeneity concerns, used weather derivatives to study the effect of hedging and risk management as an exogenous shock to firms. They do their analysis on 203 US energy utilities from 1960 till 2007 and find using derivatives results in higher valuations, investments, and leverage.

Ahmed et al (2013) test the effect of hedging by financial derivatives (foreign exchange, interest rate, and commodity price risks with futures, forward, option, and swap contracts) on firm value and financial performance using data of 288 non-financial UK firms from 2005 to 2012. Results show that interest rate risk hedging affects negatively the firm financial performance for the overall hedging but positively for the hedging with forward contracts.

The beforementioned ambiguous effect of hedging on firm value and risk particularly when it comes to interest rate hedging activities could convey the different incentives of doing interest rate hedging and using derivatives. The impact of interest rate derivatives on firm value could be divided into two groups of interest rate derivatives, first enforced by creditors and second ones used voluntarily, as Marami and Dubios (2013) have done. They defined voluntary hedging positions as derivatives for corporate risk management practices and those for private benefit of managers versus mandatory hedging positions that are referred by shareholders and obliged by creditors. They classify these mandatory instruments as real risk management practices and reward such positions by a premium on firm value. For this study, they constructed a sample of 3881 firm-years from 1998 to 2005. Results indicate that voluntary hedging positions are gained for corporate risk management practices or private benefit of managers don't have a positive impact on firm value matching risk management theories. Although the fact that interest rate derivatives have no managerial incentive and shareholders refer to mandatory terms obliged by creditors could be presumed as real risk management practices and using them will result in firm value increase.

Hang et al (2020) study the interaction between capital structure decisions and risk management decisions, plus the channels they add value to firms. They study theories on the subject by using meta-analytic structural equation modeling (MASEM) on 411 empirical studies. They find that capital structure mediates the relation between hedging and firm value and risk management positively affects leverage by providing greater debt capacities, also leverage has a negative impact on firm value. Therefore, capital structure and hedging decisions appear rather as complements instead of substitutes and managers use internal funding and leave some debt capacity unused. According to findings, corporate hedging adds value to a firm by lowering bankruptcy risks and underinvestment risks.

Geyer-Klingeberg et al (2020) exploit meta-regression analysis to accumulate hedging premium reported in 71 previous studies and found that the reported firm value effects of hedging are systematically higher for foreign exchange hedgers as compared to interest rate and commodity price hedgers. Furthermore, considering operational hedging strategies plus financial ones will significantly affect hedging premiums in a positive direction. Finally, the study shows that according to the existing literature as best samples an overall hedging premium for foreign currency hedgers is 1.8%, and the effect of interest rate and commodity price hedging decrease firm value by -0.8% and -0.6% respectively.

Interest rate hedging usually will be done by using swap derivatives. But, using derivatives according to empirical studies is not always a way to do hedging and is not assumed especially by non-financial firms as a hedging instrument. Most firms use derivatives for speculation and not for hedging so when we survey the effect of using derivatives (IR hedging) on firm value and risk, respectively negative and positive (and sometimes non-significant) effect of using hedging is reported which is in contrast with literature and our expectation of the positive effect of hedging on firm's performance.

Daniel Covitz and Steven A. Sharpe (2005) analyzed detailed information on the debt structure and interest rate derivative positions of nonfinancial firms in 2000 and 2002 and find that larger firms tend to limit their interest rate exposures, but they do so through their choice of debt structure rather than with derivatives. They don't find any evidence that nonfinancial firms hedge interest rate exposures from their operating assets, but do not see this as supporting the hypothesis that firms use derivatives to speculate.

Mnasri, Dionne, and Gueyie (2017) test the hedging maturity effects on the firm value on US oil producers using quarterly data of 150 US oil producers for 1998-2010. Hedging maturity positively affects the likelihood of financial distress and oil spot prices but the slope is decreasing. They used the essential heterogeneity approach for assessment of the causal effects of hedging maturity on firm value. Results show that MTE (Marginal Treatment Effect) is increasing and different unobserved (latent) features of oil producers influence the causal effects. Moreover, the marginal firm value increases with short-term hedging maturity.

Dan et al (2005) analyze 46 large Canadian oil and gas companies from 2000 through 2002 data to identify the role of hedging on firm value. Using generalized additive models, they find that nonlinear factors have an impact on stock returns and firm value. They find a positive effect of oil hedging on risk in large Canadian oil and gas firms, although gas hedging is more effective when downside risk is present. Plus, there is a positive significant effect on stock returns when the oil prices are increasing, and conversely.

Kumar and Rabinvitch (2013) surveyed the hedging and its effect on firm performance and particularly entrenchment in the oil and gas industry by using the information on the derivative positions of upstream oil and gas firms during 1996-2008, and concluded that hedging intensity affects positively CEO entrenchment and free cash flow agency costs. The results are consistent with the predictions of the risk management and agency costs works in the literature.

One of the best studies on the effect of hedging activities on firm value, risk, and performance features in the Oil producers' industry is done by Dionne and Mnasri (2018) who used essential heterogeneity models for bias related to selection on unobservable features and self–selection in the estimation of marginal treatment effects (MTE). They used quarterly prepared data of 413 US oil producers from 1998 till 2010. Results show that more propensity for using extensive hedging activities oil producers, will have higher causal marginal firm value and higher marginal risk reduction, and experience better marginal accounting performance and also experience significant average treatment effects (ATE) on firm financial value, idiosyncratic risk, and systematic risk.

Gilje and Taillard (2015) have studied the way and reason of hedging effects on some firm's features. For overcoming the endogeneity problems in the hedging survey, they introduced an exogenous change in basis risk in the oil and gas industry on the data of Canadian and US firms' data where the four quarters from Q1 2011 to Q4 2011 were defined as pre-event window; and the four quarters after the event from Q2 2012 to Q1 2013 as post-event window (as the first significant increase in basis risk occurs during the first quarter of 2012; they define this quarter as event quarter). Their methodology for regression was the difference-in-differences framework and found that firms affected by the basis risk shock reduce investment, lower valuations, sell assets for the reduction in associated debts to control firms. Moreover, their results provided evidence that reducing the probability of financial distress and underinvestment risk are the main important channels of hedging effects on firm value.

According to this section and the works studied, we can say that risk management's assumed beneficial effect on firm value and decreasing effect on risk could work through several indirect canals like increasing in debt capacity, liability, reduction in agency costs, and other factors. These effects depend on the way which firm uses hedging instruments.

Particularly, when it comes to using derivatives and interest rate hedging, some factors affect the way hedging affects firm performance. Some of these factors are the incentive of using derivatives (derivatives bought by speculation motivations could have a negative effect on firm performance), obligatory from debtholders (voluntary bought could result in a detrimental effect on firm performance), governance of firm (bad governance always increase the contrary result of an action), etc.

In another word, there are implications of such factors' effects on risk management which motivate firms to do more risk management and hedging. In the following, according to literature, some of these factors which may affect hedging in a firm and also may influence firm value and its risk, are presented as our variables of interest. These factors will play the role (as control and independent variables) in our model for the first step of regression on IR Hedging in US oil companies and the second step beside IR hedging effect on firm value and risk as it will be presented in the Methodology chapter.

Chapter 2
Data Description and Sample Selection

In this chapter, we define the dependent variables of interest (proxies for firm performance) which we want to set as outcome and analyze the effect of interest rate hedging (as our interested field of hedging) on. Then according to the literature and empirical works we presented before, we define other important variables which could affect firm performance and increase our model specification power. We should present other variables which could affect interest rate hedging if we faced heterogeneity, endogeneity problems (which is expected according to previous empirical works on this field). On the next step, we define more precisely the variables which we will use for the affecting factors, the source we used to extract them and descriptive statistics on variables of interest.

2.1 Sample and Data Construction

The data we will use is constructed from 139 US Oil producers with Standard Industrial Classification (SIC) code 1311 (crude petroleum and natural gas) extracted from Bloomberg which is gathered by Mohamed Mnasri. These firms meet the criteria of A) having at least five years of oil reserve data during the period 1998–2010, B) their 10–K and 10–Q reports are available from the EDGAR website, and C) the data on the variables of interest which will be presented in following is covered by Compustat (Dionne and Mnasri 2018).

For this survey, we will use quarterly gathered data for the period of 1998-2010 which gives us, unbalanced panel data of 4,511 firm–quarter observations.

In general, financial and operational features' data for this sample, have been gathered from several sources as it is indicated in table 2.1. Mohamed used Wharton Research Data Services (WRDS) to extract quarterly datasets from the Compustat library for data of financial characteristics. Other items related to institutional shareholding were taken from the Thomson Reuters dataset maintained by WRDS. In the following, we will introduce our variables of interest used as dependent, independent (outcome), control, and instrumental variables and then, in the next chapters, we will consider more precisely the data and its descriptive statistics.

We want to analyze the effect of interest rate hedging as firm risk management activities on firm performance. Three main important measures of firm performance in the context of firm performance, are value, risk, and accounting performance of the firm. So, we divided the performance into firm value-related, accounting performances, and risk-related groups. For firm value factors we use Tobin's Q, the variable of interest for accounting performance of the firm is ROE, and variables for risk are idiosyncratic risk, systematic risk, crash risk and oil beta.

In the following, we will define transparently all these 6 dependent variables (outcomes) of our essay.

1. <u>Tobin’s Q:</u> As variable for firm value which is, total assets less book value of equity plus the market value of equity, divided by the book value of assets.

We will use this in the natural logarithm in our model.

2. <u>ROE (Return on Equity):</u> A measure for accounting performance which is, the company's net income divided by its shareholders' equity.

The effect of interest rate hedging on ROE independent from the effect on Tobin's Q could show what is the difference of interest rate hedging on firm value and its accounting profits.

3. <u>Idiosyncratic Risk:</u> a type of investment risk that is endemic to a particular company's stock.

Idiosyncratic risk also refers to unsystematic risk, so the complement of idiosyncratic risk is a systematic risk, which is the overall risk that affects all assets in the industry such as fluctuations in the stock market, interest rates, or the entire financial system. So, it is important to analyze the effect of interest rate hedging on idiosyncratic risk (firm-specific risk) and systematic risk (market risk) separately.

4. Systematic Risk: Systematic risk refers to the risk which inherently exists in the entire market or market segment. Systematic risk, also known as "non-diversifiable risk," "volatility" or "market risk," affects the overall market, not just a particular firm.

5. Oil Beta: This is the sensitivity of oil industry firms' stock market returns to the fluctuation in oil prices.

6. Sigma: refers to volatility and means the amount of uncertainty or risk related to the size of changes in a security's value, or the value of a firm's equity.

7. Crash Risk: For calculating the risk of firms' stock crash in our sample we will use the firm-specific negative conditional skewness of firms' abnormal returns (NCSKEW).

We will resume with the control variables which could affect the dependant variable alongside interest rate hedging. The variables which affect firm performance are extracted from previous works and are in coincidence with the literature.

a) Firm size: To control the possible impact of size on firm value and risk management, we use the logarithm of total assets. Allayannis and Weston (2001) find a negative relation between firm value and size. Thus, we expect that Size will be negatively related to firm value.

As this variable could affect hedging decisions, we will use this for interest rate hedging estimation (First step) as a control variable too. According to literature and empirical works like Altuntas et al (2017), bigger firms hedge more so we predict positive sign for firm size in first step.

All of control variables that will be introduced in following will be used in both stages[2]

[2] . First step is estimation of instrumental variable and control variables on IR hedging dummy variable, and second step indicates estimation of effect of IR hedging on firm value and risk and finding causality results

b) Earning per share from operations: It is combined (consolidated) net earnings divided by the number of shares of common stock at the end of the Performance Period (the interested quarter). We predict earning per share impact negatively the IR hedging and positive effect on firm value.

c) Investment opportunities: We used CAPEX as a proxy for each firm's investment opportunity at the quarter of interest divided by the net property, machinery, and equipment at the start of the quarter. According to literature, we predict positive effect of investment opportunities on hedging and firm value to protect their internal financing recourses as Froot et al (1993) explains.

d) Leverage ratio: We used the book value of debt divided by the book value of assets as a measure for this variable. This factor assesses the ability of a company to meet its financial obligations. Predicted sign of leverage ratio is positive for both stages as financially constrained firms hedge more. On the other hand, bigger leverage ratios increase financial distress costs in firm and increase firm risk and decrease firm value. So predicted sign of leverage on firm value is negative and positive on firm risk.

e) Liquidity ratio: This is equal to book value of cash and cash equivalents (a percentage of non-complete cash assets) to book value of liabilities. We predict that lower liquidity ratio could result in more hedging activities to confront financial constraints and produce more indirect value for the firm by affecting hedging decisions. On the other hand, liquidity ratio has direct positive effect on firm value. So, negative effect on IR hedging and positive effect on firm value is predicted.

f) Dividend payout: This is a dummy variable that gives one to firm-quarters which was a dividend declaration and 0 for not dividend declarations. Less dividend payouts will result in more need to do hedging so predicted sign of dividend payout in IR hedging estimation is negative and predicted sign in firm value estimation is positive.

g) Institutional ownership: measures the percentage of firm shares that are held by institutional investors. As it could affect the ability of hedging by managers, we will use it in both steps. More institutional ownership could provide better governance and organization risk management activities which result in more IR hedging too, and could produce more value for the firm. We predict positive sign for institutional ownership in both estimations.

h) Oil reserves: is the all developed proved resources plus undeveloped oil resources volume (Mb) in logarithm. Producers which own more reserves will be more effected from hedging activities so they could be more interested in doing IR hedging activities to increase the firm value. We predict positive signs for this variable and gas reserves in both steps of estimation.

i) Geographic diversification of oil production activities: We use the Herfindahl Index which is equal to squared market share for each geography (continental separation is considered) and then adding the squares, the result has to be subtracted from one. Like the formula, q_i is the daily oil production in each geographic region (continent) and Q is the daily total amount of oil production of the firm. An average amount of the variable for each quarter will be used.

$$Geo_{diversification} = 1 - \sum_{i=1}^{N} \left(\frac{q_i}{Q}\right)^2$$

This variable will be used in both steps as a control variable as previous empirical works show the effect of this variable on hedging decisions and show a negative effect of geographic diversity of oil and gas on hedging activities since more centralized companies expose more risks and need more hedging activities to overcome their risks. Negative signs for oil and gas geographic diversification in first step is expected. The effect of geographic diversification on firm value is not obvious but more diversity could result in less risk for oil producers.

j) Oil production risk: is the variation of daily oil production and will be calculated using rolling windows of 12 quarterly observations. As, for some of the firms, data is reported annually, the same observation will be used for all quarters of a year. More oil production risk could force firms to do more hedging activities to overcome the uncertainty, so we predict positive signs for oil and gas production risk in hedging estimation.

k) Oil spot price: we use the West Texas Intermediate (WTI) index represented by the New York Mercantile Exchange (NYMEX) at the end of the current quarter. The higher oil spot price could result in less need for doing hedging activities so negative sign of oil spot price on hedging estimation and positive effect on firm value is predicted. For the same reason the sign of gas spot price in IR hedging estimation could be negative and positive for firm value estimation.

l) Oil price volatility: This is calculated by the standard deviation of daily spot prices of oil in the quarter of interest. More oil price volatility is translated in more risk for oil producers and more need to do hedging. Positive signs for oil price volatility and gas price volatility in first estimation (IR hedging estimation) is expected.

m) Cash flow volatility: We calculate cash flow volatility as the variance of five years' operating cash flows scaled by total assets. According to Froot et al (1993), cash flow volatility may result in value-reducing underinvestment. Since cash flow volatility can cause expensive external underinvestment problems, we expect this variable to impact negatively the firm value. According to empirical works, this variable could affect strongly the hedging decisions so we have to also use it in the first step and according to Altuntas et al (2017), predict negative sign for that in estimation of IR hedging.

n) Gas reserves: the all developed proved resources plus undeveloped gas resources volume (in billions of cubic feet) in logarithm.

o) Geographic diversification of gas production activities: We use Herfindahl Index for gas geographic production diversity as we used for oil.

p) Gas production risk: is the variation of daily gas production and will be calculated using rolling windows of 12 quarterly observations.

q) Gas spot price: calculated as an average index established from principal locations' indices in the US. (Gulf Coast, Henry Hub, etc.).

r) Gas price volatility: This is calculated by the standard deviation of daily spot prices of gas in the quarter of interest.

s) CEO stockholding: The percentage of stock shares of the firm which is held by the CEO in each quarter. According to literature chapter CEO stockholding is predicted to affect positively hedging and firm value and negatively impact firm risk.

t) CEO option holding: Quantity of firm's options held by CEO in each quarter divided by 10,000 for have analyzable coefficient. This variable is expected to have negative impact on hedging decisions.

u) Number of analysts: Number of financial analysts who cover the firm info follow its activities and do predictions on its earning quarterly. The more analysts cover a firm, the less information asymmetry is about the firm and in that sense, fewer hedging activities are needed. So, this variable’s predicted sign in hedging estimation is negative where it could positively affect firm value as it decreases the agency problems.

The most important dependant variable which we want to consider its effect on firm performance and value and risk-related features is Interest Rate Hedging of the firm. For this variable, we will use a dummy variable for each firm-quarter that gives 1 for firm-quarter which interest rate hedging have been done in mentioned quarter and firm and zero to the firm-quarter without interest rate hedging. This variable could be considered as treatment. Therefore, firms with 1 for IR Hedging which are benefited from IR hedging in a quarter are treated and firm-quarter which gets 0 (nor receives IR hedging) is untreated.

As it was indicated, some of the mentioned variables which affect firm performance factors are related to IR hedging decisions too. So, there could be a relationship between control variables and the main independent variable in our model that cause endogeneity problem. To overcome this problem, we need to use methods like Essential Heterogeneity methods, or more normal traditional two-step estimation. Using any of these methods will need an Instrumental Variable (IV). So, to analyze the effect IR hedging (treatment effect) on firm value and risk two-steps of estimation is needed, first estimation of instrumental variable on IR hedging (in presence of the control variables) and in the second step, the effect of predicted IR hedging on firm value and risk (in presence of the same control variables) will be considered. The methodology will be defined more precisely in detail in methodology chapter, but this introduction will remind us of the importance of selecting instrumental variable for IR Hedging decision (Dummy variable which is 1 for when a firm does IR hedging and 0 for when it doesn't do IR hedging)

2.2 Instrumental Variable

Method of using Instrumental Variable in two-steps least squares regression (or newer methods) could help us to overcome endogeneity problems which are because of each one of omitted variables and/or measurement error on explanatory variables. (Angrist and Krueger 2001). An instrumental variable is a variable which does not directly impact the outcome (dependant variable) and so the omitted variables and measurement errors do not affect it, but it affects the explanatory variable that is the reason of endogeneity and has to be instrumented. Relevancy of an instrument is how the instrument variable explains the changes in the variable of interest and be a good predictor of that. The validity of instrument or exclusion principle is that the instrument does not affect directly the outcome and we can say that it provides an exogenous shock or randomization in the model. The validity of instrumental variable which investigates its irrelevancy to dependent variable and playing the role of random assignment is very hard to be investigated.

Therefore, finding an instrumental variable that is valid and relevant, affects the variable of interest (IR hedging in our model) in a strong way, and does not affect the dependent variable (firm value and risk in our model) is hard and at the same time the main important part of using this method.

We use previous research showing a significant impact of oil market conditions (oil spot price and volatility) on oil hedging decisions in terms of maturity and vehicles for selecting our instrumental variable. The most important fundamental factor that determines industrial commodity prices is demand pressures or shocks induced by real economic activity. Dionne and Mnasri (2018) in the process of looking for an instrument that can explain the hedging of oil price and that cannot directly affect the value, riskiness, and accounting performance of an oil producer, used the Kilian (2009) index as an instrument for hedging in oil firms.

Kilian (2009) developed an index of global real economic activity (REA) using data of dry cargo single voyage ocean freight rates. Since 2009, this indicator has become a popular choice to represent global real economic activity, in particular for oil price studies. This instrument measures the component of true global economic activity that derives demand for industrial commodities. The Kilian index, constructed monthly, sets fixed effects for different routes, commodities, and ship sizes, deflated with the US consumer price index, and linearly detrended to remove the decrease in real term overtime of the dry cargo shipping cost. Kilian's index also does reasonably well for the properties of global output growth.

Kilian (2009) shows that aggregate shocks for industrial commodities cause long and more persistent changes in the real oil prices which is completely different from the transitory increases and decreases in the price of oil caused by oil market-specific supply shocks. Kilian's main critique is that OECD industrial production excludes emerging economies in Asia such as China and India, whose demand for industrial raw materials is thought to be fueling the surge in industrial commodity and oil prices since 2002.

For the instrumental variable, we calculate the changes in the Kilian (2009) index for each quarter. Kilian index changes are calculated by subtracting the index's level at the end of the current fiscal quarter (at last month) from its level at the end of the previous quarter.

According to Dionne and Mnasri's (2018) work a high correlation of 76.7% is showed between the Kilian index and the crude oil near-month futures contract price. So, an increase in demand for industrial commodities is correlated with an increase in futures contract prices. As a result, an increase in the Kilian index will be translated into an increase in future contract prices which could result in less oil hedging intensity, as hedging could deprive firms of privileges of price increases in the oil industry. In that sense, when buying derivatives, particularly interest rate swaps (that we presume them as IR hedging activity), is assumed as a risk management activity for oil producers, Kilian index changes and IR hedging can have a positive relationship. On the other hand, if buying derivatives which we assume as hedging activities, just assumed as a way of speculation for managers, more increase in Kilian index which means more beneficial oil markets, could result in more derivative buying for speculation by managers and, so positive effect of Kilian index changes on IR hedging could be expected.

We discussed before that the control variables can affect both IR hedging and firm value and risk, so we can use them in both steps of estimation (estimating instrumental variable on IR hedging and IR hedging on firm value and risk) as control variables, it is what we will do for all the control variables

2.3 Variables of model and their sources

Now we will present a table of variables which we will use in our model containing the names in codes, the predicted signs of variables in estimation of IR hedging (first step) and estimation of firm value and risk estimation (second step), and the source we gathered them in table 2.1.

Table 2.1: Variables which will be used in our model and their predicted signs in IR hedging, firm value and firm risk estimations

Variable Definition	name in coding (Predicted signs)	Source	Variable Definition	name in coding (Predicted signs)	Source
Dependent Variables			Main Independent Variable (Treating Variable) (Predicted sign on firm value and risk respectively)		
Firm Value (Tobin's Q) in log	tobinsq	CRSP/Compustat	Interest rate hedging (Dummy Variable)	IRhedge (o)(+) (-)	Compustat
ROE (Return on Equity)	returnequity	Compustat	Instrumental Variable (Predicted sign on IR hedging estimation)		
Idiosyncratic Risk	idrisk_std_v2	CRSP/Bloomberg	Changes in Kilian index (ΔKilian)	kilian_delta (-)(o)(o)	Federal reserve of Dallas Website
Systematic Risk	mktrf_beta_v2	CRSP/Bloomberg	Control Variables (Predicted sign on IR hedging, firm value, firm risk) respectively		
Oil Beta	oil_beta	CRSP/Bloomberg	Oil production risk	oilprod_cv12 (+) (NA) (+)	Manually constructed Bloomberg and 10–K reports
Sigma (Volatility)	sigma	CRSP/Bloomberg	Oil spot price	oilspot (-) (+) (-)	Bloomberg
Crash Risk	ncskew	CRSP/Compustat	Oil price volatility	oilvol (+) (-) (+)	Manually constructed
Control Variables (Predicted sign on IR hedging, firm value, firm risk) respectively			Cash flow volatility	fcf_volatility (-) (-) (+)	CRSP/Compustat
Firm size (in log)	firmsize_log (+) (-) (+)	Compustat	Gas reserves	gas_res (+) (+) (-)	Bloomberg and 10–K reports
Earning per Phare from operations	epsop (-) (+) (-)	Compustat	Geographic diversification of gas production activities	diversifigas (-) (NA) (-)	Manually constructed
Investment opportunities	in_opp (+) (+) (-)	Compustat	Gas production risk	gasprod_cv12 (+) (NA) (+)	Manually constructed Bloomberg and 10–K reports
Leverage ratio	levliab (+) (-) (+)	Compustat	Gas spot price	gasspot (-) (+) (-)	Bloomberg
Liquidity ratio	liquidity (-) (+) (-)	Manually constructed	Gas price volatility	gasvol (+) (-) (+)	Manually constructed
Dividend payout	dvdpayout (-) (+) (-)	Manually constructed	CEO stockholding	ceocs (+) (+) (-)	Thomson Reuters
Institutional ownership	instown (+) (+) (-)	Thomson Reuters	CEO option holding	ceooptions (-) (-) (+)	Thomson Reuters
Oil reserves	oil_res (+) (+) (-)	Bloomberg and 10–K reports	Number of analysts	num2_qtr (-) (+) (-)	IBES
Geographic diversification of oil production activities	diversifioil (-) (NA) (-)	Manually constructed			

Note: the signs in parentheses indicate the sign of coefficient of the variable respectively from left in IR hedging regression, firm value, and firm risk estimations.

Now we are ready to go to the next step and introduce the method we use for analyzing our data, and our model specification for acquiring reliable results. As mentioned before, the endogeneity problem, the effect of self-selection, and the inherent feature of analyzing financial issues, are the main important reasons that we will face and it is necessary to use valid and relevant instrumental variable through a good-defined methodology.

Chapter 3
Methodology

We studied in the previous chapter that the most important source of inconsistency in the previous works came from the endogeneity problem in the models used in regression on the effect of hedging on firm features. To overcome this problem, we used an instrumental variable but there is another unsolved problem with such model because of the self-selection problem. For overcoming such problem, we need to use other models like the essential heterogeneity model with instrumental variable.

3.1 Basic model specifications

The base model for an estimate of the effect of interest rate hedging on firm performance could be defined as following which we can do it by basic methods like *ordinary least square* or *maximum likelihood* models (Mincer, 1974):

$$Y_{i,t} = \alpha + \beta_1 d_{i,t} + \sum_{j=2}^{N} \beta_j (CV)_{ji,t-1} + \epsilon_{i,t} \qquad (3.1)$$

Where i represents firms, t represents each quarter, $Y_{i,t}$ is the output of our model (firm value, idiosyncratic risk, systematic risk, ROE…) for each firm-quarter, α is the intercept of the model, $d_{i,t}$ is a dummy variable for interest rate hedging which gives one for firm-quarter which does interest rate hedging and 0 for non-hedgers (as we are going to use instrumental variable in such equation 1 goes for predicted hedgers and zero goes for predicted non-hedger firm-quarters) and β_1 is its effect on the dependent variable and show the average treatment effect or average return on dependent variable due to doing IR hedging. $(CV)_{ji,t-1}$ represents N observed control variables introduced in table 2.1 for each firm-quarter presented in first lag, and $\epsilon_{i,t}$ is the error term specified for each firm-quarter.

As we studied before the probability of having an endogeneity problem due to correlation between $d_{i,t}$, and $\epsilon_{i,t}$ (or even with other control variables) will cause the standard selection bias we face in models analyzing financial issues. It will be tackled by using methods like instrumental variables, regression discontinuity, and selection models. We opt for the instrumental variable method (IV) as a conventional method to overcome this bias.

The second source of selection bias comes from the correlation between β_1 and $d_{i,t}$ which means the coefficient of IR hedging effect on firm performance is random. In other words, the effect of IR hedging on firm performance is not constant and it could change from one firm to other. This problem is related to unobserved variables which impact both firm performance and IR hedging decisions together. Some of these unobserved variables could be the governance of the firm, managerial behavior, economic environment, policies, and financial markets conditions, etc. For example, if we assume two firms have exactly the same control variables and did hedging too, but they have different managers which one is more risk-taker, if the economic environment is better, the risk-taker could take less IR hedging but better firm performance, so the effect of doing IR hedging for these two firms could be different (possibly different β_1s for each hedged firm).

As we discussed in previous paragraph, returns of hedging could vary (i.e., $\beta_1$is random) and firms act as if they possess some knowledge of their idiosyncratic return (i.e., $\beta_1$is correlated with $d_{i,t}$). Selection on gains complicates the estimation of the marginal effect of hedging or marginal treatment effect (MTE).

Heckman, Urzua, and Vytlacil (2006) and Carneiro, Heckman, and Vytlacil (2010) showed that an instrumental variable estimator identifies a Local Average Treatment Effect (LATE), which measures the outcome of hedging for individuals induced to do that by the change in the Kilian index (instrumental variable). But unfortunately, the firm motivated to do hedging because of a change in the instrumental variable could not necessarily experience the same effect on firm value and risk as the firms advised to do IR hedging by a given unobserved variables change which could affect firm performance (outcomes) simultaneously. So, the returns (of doing hedging) to the two hedging firms are very likely to differ. This is what Heckman and others named as heterogeneous treatment effect or *essential heterogeneity*.

3.2 Essential Heterogeneity model

We will use Heckman et al (2005, 2006, 2010)'s way and use a local version of instrumental variables to overcome essential heterogeneity and estimate the marginal returns to alternative ways of producing marginal expansions in IR hedging without requiring that the variation in the Kilian index (as our available instrument) correspond exactly to the variation induced by other unobserved factors. They named this way as *essential heterogeneity method* which controls for the individual-specific unobserved heterogeneity in the estimation of marginal treatment effects (MTEs) of doing IR hedging versus non-hedgers. The calculations and algebra which we use to get essential heterogeneity model is presented in appendix A in details. In here we just introduce main steps and final model.

In Roy model we face an equilibrium model for work selection. The generalized Roy Model is a basic choice-theoretic framework for decision analysis. According to difference between IR hedged firms and non-hedged ones, one can assume two estimations (equations 3.2 and 3.3) on output as following:

$$Y_{0i} = \alpha_0 + X_{ij}\beta_{0j} + U_{0i} \qquad (3.2)$$

$$Y_{1i} = \alpha_1 + \beta_1 + X_{ij}\beta_{1j} + U_{1i} \qquad (3.3)$$

$$Y_D = DY_{1i} + (1 - D)Y_{0i} \qquad (3.4)$$

$$I_i = \theta Z_i - V_i \qquad (3.5)$$

$$D = \begin{cases} 0, & I_i < 0 \\ 1, & I_i \geq 0 \end{cases} \qquad (3.6)$$

Conditional on counterfactual treatment decisions, Y_{1i} is the potential output of firm performance (firm value or risk) if the firm does IR hedging (treated firm), Y_{0i} is potential firm performance (firm value or risk) if the firm doesn't IR hedging (not treated). Firm performances are linearly dependent on X_{ij} (observed control variables) and unobserved components of U_{0i} and U_{1i} as error terms and β_1 $(in\ eq. 3.1)$ is the benefit of being treated (doing IR hedging).

The decision process for the treatment (whether do IR hedging or don't) indicator is I_i which is posed as a function of observables Z_i (control variables plus instrumental variable (delta Kilian index)) and unobservables V_i. So, according to 3.4, 3.5, and 3.6 equations, the decision process for treatment is linked to the observed firm performance (Y_D) through the latent variable (I_i). If the answer of equation 3.5 after estimation of coefficient θ by using a bunch of control variables plus instrumental variable become less or equal to zero then D goes to 0 and $Y_D = Y_{0i}$ shows an untreated firm-quarter. If I_i becomes bigger than zero, D becomes 1 and shows a treated firm-quarter and $Y_D = Y_{1i}$.

Through this parametric approach, the discrete choice model (equation 3.5) for firms to do IR hedging is just a conventional probit ($V \sim N(0,1) \rightarrow {\sigma_v}^2 = 1$) and the propensity score is given by:

$$P(z) = Pr(D = 1|Z = z) = \Pr(I > 0) = \Pr(\theta Z > V) = F_v(\theta Z) = \Phi(\theta Z) \quad (3.7)$$

Where $P(z)$ denotes the probability of doing IR hedging conditional on Z=z. If we define $U_D = F_v(V)$, U_D as a cumulative distribution of standard normal variable V will be uniformly distributed, and different values of V will give out different values of U_D. So, by using 3.7, we have:

$$P(Z) = F_v(\theta Z)\,,\ D = 1\ (treatment\ is\ done)\ if\ P(Z) \geq U_D \qquad (3.8)$$

$$or\ equivalantly:\ \Phi(\theta Z) \geq \Phi(V)$$

Using equation 3.8 we can interpret $P(Z)$ (propensity score) as the probability of being treated or doing IR hedging and U_D as the resistance against being treated in each firm from unobserved variables. So, the bigger $P(Z)$ means more probability to oil producers to do IR hedging and a bigger U_D will entice oil producers more to do not go for IR hedging decisions. And when $P(Z) = U_D$ is the indifference level for an oil producer to resist against doing IR hedging or do that. Hence, after some manipulation on equations which are presented in detain in appendix A we have:

$$MTE = E(Y_1 - Y_0|X = x, U_D = u_D) = (\alpha_1 + \beta_1 - \alpha_0) + X_{ij}(\beta_{1j} - \beta_{0j}) + E(U_1 - U_0|X = x, U_D = u_D) \qquad (3.9)$$

$$ATE = E(\beta_1|X = x) = E(Y_1 - Y_0|X = x) \quad (3.\ 10)$$

Since we will work on essential heterogeneity model through the parametric method for estimating our model's parameters according to Brave and Walstrum (2014) and Dionne and Mnasri (2018) we have:

$$E(U_1|X = x, U_D = u_D) = E(U_1|X = x, P(Z) = p, D = 1) = \sigma_{v1}\left(-\frac{\phi(p)}{p * \Phi(p)}\right) \quad (3.11)$$

$$E(U_0|X = x, U_D = u_D) = E(U_0|X = x, P(Z) = p, D = 0) = \sigma_{v0}\left(\frac{\phi(p)}{(1-p) * \Phi(p)}\right) \quad (3.12)$$

We can use equations 3.11 and 3.12 for calculation of Y_0 and Y_1 and use equation 3.9 for final the calculations on MTE.

The parameters σ_{v0} and σ_{v1} are the inverse Mills ratios coefficients, and right-hand-side expression in 3.11 and 3.12 are inverse Mills ratio for treated and untreated samples which we will see as $\sigma_{v1} - \sigma_{v0}$ (which in Stata it is named as $(\rho_1 - \rho_0)$). So, we can rewrite 3.9 as following:

$$MTE(X = x, U_D = u_D) = E(Y_1 - Y_0|X = x, U_D = u_D) = \quad (3.13)$$

$$(\alpha_1 + \beta_1 - \alpha_0) + X_{ij}(\beta_{1j} - \beta_{0j}) + E(U_1 - U_0|X = x, U_D = u_D) =$$

$$(\alpha_1 + \beta_1 - \alpha_0) + X(\beta_{1j} - \beta_{0j}) + (\sigma_{v1} - \sigma_{v0})\Phi^{-1}(u_D)$$

Finally, for estimating marginal treatment effect we can use the estimated propensity score (P(Z)):

$$MT\widehat{E(x, u_D)} = \widehat{\alpha_1 + \beta_1} - \widehat{\alpha_0} + X(\widehat{\beta_{1J}} - \widehat{\beta_{0J}}) + (\widehat{\sigma_{v1}} - \widehat{\sigma_{v0}})\Phi^{-1}(u_D) \quad (3.14)$$

According to definition, the way that MTE changes over the range of unobserved resistance on doing IR hedging which is given by the cumulative distribution of error terms in regression of instrumental variable and control variables on IR hedging decision ($U_D = \Phi(V)$), is a sign of the existence of the heterogeneous treatment effects in our oil producers' sample. This change is the way which β_1 (the coefficient of doing IR hedging) in the firm performance estimation model is correlated by U_D as "treatment indicator".

Identically, the estimated changing MTE shows how a rise in the marginal outcome (firm value, risk) by going from choice non-IR-hedgers to doing IR hedging varies with different quantiles of the unobserved component V in the choice equation. As $U_D$shows the latent unobserved resistance of doing IR hedging, when MTE increases (decreases) with U_D means that the coefficient β_1 is negatively (positively) correlated with the latent tendency of using IR hedging for oil production.

In the next chapter, we will start with becoming more familiar with our sample and its descriptive statistics, then we go forward and construct our model and do estimation using the *parametric method* of *essential heterogeneity model* and present 2-step regression coefficients (step one: regression on IR hedging, step 2: regression on firm performance features like firm value and risk) results as well as ATE and causal effects (MTEs).

Chapter 4
Presentation and Analysis of Results

We have become familiarized with the method and model which we are going to use to analyze the effect of selected characteristics of firms and the oil market on IR hedging decisions and the impact of IR hedging (ordinary coefficients, ATE, and MTE) on firm value and risk. As it was indicated in chapter 2, we have access to a sample for the period 1998-2010 of US oil producers which gives us 4,511 firm–quarter observations after dropping not available data for some firm-quarter variables. In the following, we will become more familiar with our sample by reviewing its descriptive statistics and how hedgers and non-hedgers are different from each other regarding variables of our model, and then move forward to estimate the *2-step parametric method of our essential heterogeneity model* as well as analyzing the results.

4.1 Descriptive Statistics

We make a statistical analysis over our quarterly constructed data sample of 139 US oil producers in 51 quarters (from the second quarter of 1998 till the last quarter of 2010)[3]. As we don't have data on whole variables in entire quarters for all of the 139 firms, the number of observations (the firm-quarters) for variables is less than 139*51=7089 and is equal to 4511 observations for all variables. Statistical information on the mean, the median, first and third quarter of data, and standard deviation of independent variables of our model for the whole sample are presented for variables of our model in table 4.1.

Table 4.1 shows that oil producers' size in log on average is 6.853 (M$) and median is almost at the same amount (6.72M$) which shows that the distribution of oil producers in our sample follows approximately the normal distribution. The average earnings per share from operations of our sample firms is almost US$ 0.27 with a slightly right-skewed distribution as the mean of EPS is less than mean but not so far (US$ 0.18).

[3] . We have lost data on the last quarter of 1997 and the first quarter of 1998 because we needed Delta Kilian Index for our model which shows the changes in Kilian Index, so the first quarter had been lost, and as we use lag of independent variables in our model so second quarter was lost too.

Table 4.1: Descriptive statistics of our model's independent variables

Variable	Mean	First quartile	Median	Third quartile	Standard deviation
Firm size (in log)	6.853	5.293	6.722	8.383	2.287
Earning per Share from operations	0.279	-0.02	0.18	0.61	1.347
Investment opportunities	0.089	0.036	0.060	0.100	0.171
Leverage ratio	0.532	0.400	0.540	0.656	0.240
Liquidity ratio	1.011	0.066	0.217	0.599	3.447
Dividend payout (0/1)	0.337	0	0	1	0.473
Institutional ownership	0.425	0.044	0.422	0.758	0.345
Oil reserves (in log (Mb))	2.626	0.886	2.653	4.502	2.849
Geographic diversification of oil	0.122	0	0	0	0.248
Oil production risk	0.249	0.077	0.153	0.310	0.276
Oil spot price	51.960	26.86	49.64	70.68	28.467
Oil price volatility	3.482	1.671	2.674	3.847	2.959
Cash flow volatility	0.038	0.014	0.027	0.044	0.048
Gas reserves (in log BCf)	5.097	3.463	5.303	6.954	2.695
Geographic diversification of gas	0.077	0	0	0	0.197
Gas production risk	0.242	0.085	0.163	0.310	0.251
Gas spot price	5.231	3.409	4.895	6.217	2.579
Gas price volatility	0.755	0.348	0.508	1.111	0.549
CEO stockholding	0.004	0	0	0.002	0.010
CEO option holding (number*10,000)	16.466	0	0	15.72	40.898
Number of analysts	6.769	1	4	11	7.375

Oil producers in the sample invest on average the equivalent of 9% of their net property, plant, and equipment in capital expenditure; where the median is almost 6% and more away from the mean so the distribution is right-skewed and a lot of firms experience a lower percentage of investment on CAPEX. Descriptive statistics also indicate that oil producers have high leverage ratios The average leverage ratio is about 53% and the median is 54% and distribution is almost normal but a little bit skewed to the left, which indicates that some of the oil producers were working by very little proportion of liability (maybe not able to borrow or go on debts) but the most proportion of firms' debts are bigger than half of their assets.

Moreover, some oil producers maintain high levels of liquidity reserves, as measured by cash on hand and short-term investments. The average quick ratio is about 1.011 where the median is far less and 0.217 indicating highly positive skewness. So, we are facing a sample that includes some firms with high levels of liquidity whereas the majority of firms work on the level as one-fifth of the mean liquidity level of the sample. One-third of the oil producers in the sample pay dividends.

Institutional ownership has a mean and median of about 42% and varies from just 5 percent of institutional ownership for the first quartile to higher than 76% for the top quartile. This variable follows an almost normal distribution.

The mean quantity of summation of developed and undeveloped oil reserves, in logarithm, is 2.625 which corresponds to a quantity of about 358 million barrels of oil for oil reserves. The median of oil producers' reserves in the log is approximate as mean (2.653) which indicates a fairly normal distribution.

The Herfindahl indices, which measure geographical dispersion of daily oil and gas production, have an average value of 0.122 for oil and 0.077 for gas, indicating that oil and gas producing activities are highly concentrated in the same region. For oil and gas producing median is zero but for oil case, the standard deviation is 0.248 (and 0.197 for gas producers) which shows that although a majority proportion of oil producers are ultra-centralized on a geographic area there are a small number of firms with well-diversified oil sources and the distribution has positive skewness. (The skewness is weaker in gas production geographic sources distribution).

Table 4.1 further shows relatively stable oil and gas production quantities, with an average coefficient of variation in daily production of 0.249 for oil and 0.242 for gas production which shows a slight difference but the median for oil production is 0.153 where it is 0.163 for gas production shows the more diversified distribution of oil production in comparison with gas production to a right-skewed distribution.

In the period of our interest where the data is gathered the oil spot price has been on US$51.96 and the median of prices have been about US$49.64, the maximum oil price in this period was US$140. Except for some extreme amounts (positive and negative), prices are normally distributed and the volatility of oil prices was on average about 3.48 with positive skewness.

Cash flow volatility in oil producers of our sample was on average of 0.038 and the median of cash flow volatility of firms was 0.027 with high right-skewed distribution indicating that a lot of firms have smoother and flat cash flow with a little volatility but there is a minor proportion of firms which experience very highly volatile cash flow.

The gas reserves in logarithm have a mean of 5.097 which corresponds to a quantity of about 1,947 billion cubic feet of gas reserves. The median of gas reserves in the log is approximate as mean (5.3) which indicates a fairly normal distribution like oil reserves but a little bit of skewness to left.

In comparison with the oil spot price, in the period we consider, gas price is more diversified and the gas price has a more skewed distribution (to right). The mean gas price in the period is US$5.23 and the median price is about US$4.89, the maximum gas price in this period was US$13.48. Gas prices volatilities are normally distributed and the mean is about 0.75.

On average, the CEO of our sample oil producers in the period of our study holds 0.4% of outstanding common shares of their firms and about 164,660 stock options, the median of stock holding by CEOs is 0% and 0 option holding on the median for CEOs is registered too. So, both stock and options holding have right-skewed and huge kurtosis. Option holding even has a bigger standard deviation. The last independent variable is the number of analysts following the oil producer on the quarter of interest, 6 analysts follow the firms and median of data is 4, distribution is right-skewed and a lot of firm-quarters are covered by the limited (low) quantity of analysts where some firm-quarters (which are in minority) have been followed by a large number of analysts.

Table 4.2 provides the same information about dependent variables plus IR hedging and Kilian index.

Table 4.2: Descriptive statistics of our models' dependent variables, treatment and instrumental variable

Variable	Mean	First quartile	Median	Third quartile	Standard deviation
Tobin's Q (in log)	1.701	1.150	1.432	1.864	1.069
Return on Equity	-0.015	-0.005	0.026	0.053	0.336
Idiosyncratic Risk	0.030	0.016	0.024	0.036	0.022
Systematic Risk	0.866	0.408	0.918	1.344	0.915
Oil Beta	0.179	0.036	0.175	0.321	0.292
Sigma (Volatility in equity)	0.563	0.329	0.458	0.660	0.365
Crash Risk (negative skewness)	-0.033	-0.483	-0.086	0.307	1.170
IR Hedging (0/1)	0.215	0	0	0	0.411
Kilian Index	43.134	-12.15	49.06	97.77	68.726

According to table 4.2, the oil producers' mean firm value (value scaled by the book value of assets) in logarithm is equal to 1.701 and slightly above the median, indicating the majority of firms have smaller firm values and distribution is right-skewed.

ROE as a measure for accounting performance of firms in our sample shows on average negative return on the oil producers in the period of survey and a median of slight positive returns scaled to firms' equity and a mode of positive returns for producers although the distribution has a negative tail.

Idiosyncratic and systematic risk of the sample oil producers are both almost normally distributed, showing mean of 0.030 and 0.866 and indicating that firms are facing bigger market risks in comparison with their idiosyncratic firm-specified risks. Oil beta which is the sensitivity of oil industry firms' stock market returns to the fluctuation in oil prices, is normally distributed and in our sample, there are firms more sensitive to changes in the market as well as less sensitive ones. Volatility on the value of firms' equity in the market is right-skewed and its dispersion is quite high. Crash risk also is normally distributed with a little skewness to right and inform us a big frequency of firms are exposed to lower crash risks and negative returns.

Table 4.2 shows that a lot of firms decided to don't use IR hedging instruments and on average one of five firm-quarters have done IR hedging or used instruments that could be assumed as a way to doing IR hedging. Finally, the Kilian index's volatility in the period of interest is high and dispersion is from smallest -76.43 to largest 182.14, though the distribution is near to normal with a little negative skew.

4.2 Correlation between variables

In the following, we will survey the way that dependent variables are correlated together. For this purpose, we will use pairwise which compares generally variables in pairs to be able to opine how the variables (dependent variables of our model) are correlated to each other, or have a greater amount of some quantitative property, or whether or not the two entities are identical. Using pairwise correlation allows us to detect highly correlated features which bring no new information to the dataset. Since these features only add to model complexity, increase the chance of overfitting, and require more computations, could reduce our model's efficiency. So, we can decide to drop highly correlated variables to have a better-specified model to have more precise results.

Table 4.3 provides the results of investigating correlation on independent variables in pairs. Positive coefficients indicate a positive correlation between two variables and negative coefficients, imply a negative, inverse correlation between them. The pink cells in the table show no significant correlation between two variables under 95 percent of confidence level, we can set aside these cells and only work on other cells.

Table 4.3: Correlation Matrix of dependent variables

Variables	Firm size	Earning per share	Investment opp…	Leverage ratio	Liquidity ratio	Dividend payout	Institution owning	Oil reserves	Geo diver… oil	Oil pro… risk	Oil spot price
Firm size	1										
Earning per Share	0.2613***	1									
Investment op…	-0.0486**	-0.0078	1								
Leverage ratio	0.2422***	-0.0841***	-0.0291	1							
Liquidity ratio	-0.1703***	-0.0322*	0.0273	-0.3190***	1						
Dividend payout	0.5757***	0.2392***	-0.0791***	0.0148	-0.0168	1					
Institution owning	0.6227***	0.1224***	-0.0228	0.1400***	-0.1556***	0.2494***	1				
Oil reserves	0.8225***	0.2320***	-0.0839***	0.2162***	-0.2202***	0.4973***	0.5343***	1			
Geo diver… oil	0.5145***	0.2184***	-0.0693***	0.0011	-0.0718***	0.3943***	0.2605***	0.5399***	1		
Oil production risk	-0.2179***	-0.0883***	0.1575***	-0.0117	0.0791***	-0.2165***	-0.187***	-0.3221***	-0.1862***	1	
Oil spot price	0.2202***	0.1069***	0.0536***	-0.0654***	0.0654***	-0.0242	0.2025***	0.0107	0.0045	0.0248	1
Oil price volatility	0.1320***	-0.0298*	0.0268	-0.0292	0.0351*	-0.0054	0.1192***	0.0012	-0.0044	0.0263	0.5521***
Cash flow volatility	-0.1527***	-0.1254***	-0.0791***	0.0995***	-0.0372*	-0.1248***	-0.074***	-0.0971***	-0.0422**	0.0236	0.0089
Gas reserves	0.8485***	0.2099***	-0.0779***	0.2842***	-0.2978***	0.5210***	0.5199***	0.7567***	0.3672***	-0.2792***	-0.0112
Geo diver… gas	0.4694***	0.2059***	-0.0599***	0.0043	-0.0547***	0.3526***	0.1736***	0.4952***	0.7366***	-0.1813***	0.0107
Gas production risk	-0.2318***	-0.0899***	0.1532***	-0.0769***	0.0769***	-0.2421***	-0.212***	-0.2409***	-0.1661***	0.4502***	0.0948***
Gas spot price	0.1660***	0.1343***	0.0687***	-0.0527***	0.0350*	-0.0144	0.1532***	0.0058	0.0227	0.0312*	0.6146***
Gas price volatility	0.1174***	0.1409***	0.0667***	-0.0505***	0.0226	-0.0165	0.1049***	0.0080	0.0152	0.0059	0.3675***
CEO stockholding	-0.1182***	-0.0337*	-0.0024	0.0565***	-0.0275	-0.1067***	-0.0487**	-0.0691***	-0.0826***	0.0425**	-0.1854***
CEO option holding	0.1480***	0.0343*	-0.0081	0.1032***	-0.0405**	0.0494***	0.0711***	0.0804***	0.0669***	0.0118	-0.0748***
Number of analysts	0.7940***	0.2026***	-0.0634***	0.1243***	-0.1799***	0.4569***	0.6180***	0.6813***	0.4696***	-0.1994***	0.1305***

Variables	Oil price volatility	Cash flow volatility	Gas reserves	Geo diver... gas	Gas prod… risk	Gas spot price	Gas price volatility	CEO stockho…	CEO option …	Number of analysts
Oil price volatility	1									
Cash flow volatility	0.0783***	1								
Gas reserves	-0.0005	-0.1446***	1							
Geo diver… gas	0.0077	-0.1191***	0.3224***	1						
Gas production risk	0.0673***	0.0160	-0.3011***	-0.1567***	1					
Gas spot price	0.3566***	-0.0966***	0.0066	0.0055	0.0729***	1				
Gas price volatility	0.2539***	-0.0252	0.0084	0.0038	0.0303*	0.5834***	1			
CEO stockholding	-0.1263***	-0.0289	-0.0580***	-0.0665***	0.0441**	-0.0834***	-0.051***	1		
CEO option holding	-0.0448**	-0.0419**	0.1149***	0.0483**	0.0109	0.0057	0.0134	0.6023***	1	
Number of analysts	0.0964***	-0.0846***	0.7371***	0.3374***	-0.2578***	0.0917***	0.0535***	-0.138***	0.0747***	1

Note: pink cells indicate no significant correlation between variables, and stars show the significance level according to

$*: p > 0.05$, $**: p > 0.01$, $***: p > 0.001$

According to the definition of Pearson's correlation coefficient which is commonly denoted as r, the coefficient can be used to quantify the linear relationship between two distributions (or features) in a single metric. The coefficient ranges from -1 to 1, -1 being a perfect negative correlation and +1 being a perfect positive correlation. The absolute value of the correlation coefficient could show the strength of relation and co-movement between two variables. If the absolute value of the coefficient of correlation is larger than 0.5 it shows that these variables could have moderate correlation like the cells which are shown in blue color.

For example, both gas and oil spot prices and volatility of prices have moderate correlation $(0.5 < |r| < 0.7)$, which is obviously because of market changes and the fact that these pairs of variables are related, one shows price and the other indicates the volatility in price, so changes can affect both at the same time and direction. We can waive such relationships which come from inherent similarity or one unobservable source and variable which we can not measure or even find. On the other hand, the intensity of such a relation is not so big and is classified as a moderate correlation. Some of the other moderate correlations are which are gas and oil spot prices (which come from decisions in the energy market and their shocks), oil and gas reserves, and institutional ownership (because of the volume of reserves firms could become more famous and institutions more motivated to buy their equity), and options holding and stock holding by CEO (could come to the rules, internal regulations or governing power of firm).

The cells in orange in table 4.3 indicate a strong correlation between two variables since in these cells absolute correlation coefficient is bigger than 0.7. the way which we mentioned in the previous paragraph is in effect here, we see the strong correlation between the diversity of geographic oil resources and gas geographic resources diversity which is obviously because of mobilization of oil producers' oil and gas production activities together, as the needed investment on the new field at the same geography where firms have been working could be lower, we expect a strong correlation between these two variables, the same expression is for oil and gas reserves which are correlated strongly too. Other strong correlations are between firm size and respectively gas reserves, oil reserves, and the number of analysts, moreover, the number of analysts has a strong correlation with gas reserves too. As strong correlations quantity is ignorable in comparison with 210 pair correlations of our variables, we can find that all of our variables could be used in our final (second step) model to analyze the effect of predicted IR hedging on firm value and risk.

4.3 Differences between hedgers and non-hedgers

As we discussed and as shown in table 4.2 IR hedging is used by approximately one-fifth of oil producers in our sample. More precisely, after dropping missing values, IR hedging was not done in 3,540 firm–quarters and just 971 firm-quarter do IR hedging out of 4,511 firm-quarter in our sample. So, 21.52% of the firm–quarters in the sample are IR hedgers.

Now we resume our analysis by doing a univariate test on two groups of observations of each independent variable defined by IR hedging. For this purpose, we divide our sample into two groups of hedgers and non-hedgers to compare them regarding independent variables as well as firm value, risk, and performance (dependent variables). For this purpose, we will investigate both groups' mean and median for all mentioned variables and do t-test and χ^2 tests to investigate whether the mean and median of these variables between two groups are significantly, statistically different. We remind that as variables oil price, oil price volatility, gas price, gas price volatility, and Kilian index are the market variables that do not depend on firms hedging activity and oil producers are almost taker of these variables from out of the model, these will be obviously equal for hedgers and non-hedgers, so we waive these 4 variables from our survey in this section.

Table 4.4 contains the mean and median of independent variables of hedgers and non-hedgers groups and associated tests of differences between the means and medians by IR hedging decisions. We have divided the sample into 2 subsamples (group) containing 971 observations on the IR hedging group and 3,540 observations on the non-IR hedging group. The means are compared by using a t-test (to test the equality of means) and assuming unequal variances of two groups. the medians are compared by using a non–parametric k-sample test (for the medians' equality test) and the null hypothesis is that the k samples were drawn from populations with the same median. For two groups (firm-quarters which do IR hedging and firm-quarters don't IR hedging), the Pearson's χ^2 test statistic is computed with a continuity correction.[4]

Table 4.4: Independent variables statistical characteristic and univariate test by IR hedging

Variable	1. IR hedgers		2. non-IR hedgers		Comparison btw 1 and 2	
	Mean	Median	Mean	Median	t-stat	Pearson χ^2
Firm size (in log)	7.855	7.670	6.578	6.369	-19.324***	273.142***
Earning per Share from operation	0.336	0.27	0.263	0.16	-1.196	25.609***
Investment opportunities	0.084	0.056	0.090	0.062	0.923	11.056***
Leverage ratio	0.616	0.592	0.509	0.520	-15.702***	148.349***
Liquidity ratio	0.374	0.120	1.185	0.265	9.679***	111.73***
Dividend payout (0/1)	0.426	0	0.313	0	-6.409***	43.302***
Institutional ownership	0.551	0.662	0.390	0.330	-13.916***	148.349***
Oil reserves (in log)	3.821	3.677	2.298	2.153	-19.078***	317.951***
Geographic diversification of oil	0 .118	0	0.124	0	0.6507	1.546
Oil production risk	0.220	0.144	0.258	0.156	4.143***	2.515
Cash flow volatility	0.036	0.029	0.038	0.026	2.195**	23.640***
Gas reserves (in log)	6.242	6.107	4.784	4.727	-20.224***	231.736***
Geographic diversification of gas	0.052	0	0.084	0	5.409***	0.639
Gas production risk	0.207	0.152	0.251	0.167	5.569***	8.353***
CEO stockholding	0.003	0.000	0.003	0	0.106	95.367***
CEO option holding (*10,000)	20.917	6	15.244	0	-3.498***	95.367***
Number of analysts	9.196	7	6.102	3	-11.594***	141.780***

*Note: The superscripts ***, **, and * indicate statistical significance levels of 1%, 5%, and 10%, respectively.*

The null hypothesis of both tests (t-test and χ^2test) is that the mean and the median (respectively) of variable's observations are equal between two group of IR hedgers and

[4] . As the sample size is bigger than 1000 (971 IR hedger and 3540 non-IR hedger firm-quarters) we use *median* χ^2 -test to be able to have exact results instead of using *Wilcoxon rank-sum test* t-test which could not be performed in exact type on big size samples.

non-hedgers, or in other words, the difference of means (medians) in two groups is equal to zero. When the probability and p-value are less than 5 percent indicates that the null hypothesis could be rejected at this significant percent and there is a difference between means (medians) of two groups, so the means (medians) in two treated and untreated groups (do IR hedge and don't hedge) is statistically different in a significant level of 5%. On the other side, if t-test (or χ^2test) gives probability above 10 percent (0.1), means that we statistically can’t reject the null hypothesis, so there is no statistical significance difference between the two treated and untreated groups' mean (or median) considering the variable of interest and we can't reject that the mean (or median) of variables' observation in two groups are significantly the same. Two right columns in table 4.4 indicate t-stat χ^2 and where there are three stars above the number, mean (median) of IR hedged and nonhedged firms are statistically different on a significance level of 1 percent. Two stars show a significant difference at 5% level and one star indicates significance at the level of 10%.

We observe statistically significant differences between two groups of firms regarding a lot of variables. In the context of mean differences t-test results just on EPS, institutional opportunities, geographic diversification in oil production activities, and CEO stockholding can't reject the sameness of means between two groups and when it comes to the median, chi-2 results show that two groups have the same median on oil production risk and geographic diversification in oil and gas production activities. Regarding geographic diversification of oil and gas production results show that hedgers are more centralized in comparison with firms that don't be hedged by interest rate derivatives, but the difference is not statistically significant.

As we apperceive from table 4.4, the univariate analysis generally reveals considerable differences in oil producers' characteristics between IR hedging decisions. Results show that bigger oil producers with, more EPS, fewer investment opportunities, lower cash flow volatility, higher leverage, do IR hedging that is in corroboration with Altuntas et al (2017) that hedgers may rely on more external funds and in contrast with Froot, Sharfstein, and Stein (1993) that firms hedge to protect their investment programs’ internal financing. Moreover, IR hedging decision is positively related to financial slack, so where the liquidity ratio decrease, firms don't hedge on the interest rate. But hedgers pay bigger dividends in comparison with non-hedgers which is inconsistent with the literature (Dionne and Triki, 2013) that firms with more financial constraints hedge more to decrease their default probability. IR hedgers surprisingly have higher oil and gas reserves, and lower production uncertainty which shows that these bigger, fluent firms face lower operational constraints which are assumed as a motivation to do hedging and consider risk management in the firm. This could be because that oil producers far from constraints could do better risk management activities, especially in interest rate hedging as a new risk management instrument or, maybe they assume interest rate derivatives as an instrument for speculation rather than a way to hedge risks and what we assume as IR hedging activity is more about speculation advantages than risk management.

Table 4.4 show that managerial stockholdings are, on the median, greater for oil producers to do IR hedging that is in corroboration with Smith and Stulz (1985), regarding mean t-test there isn't a significant difference between hedgers and non-hedgers. IR hedged firms have more managerial options in comparison with non-hedgers, this finding is in contrast with Tufano (1998) that risk-averse managers with higher option holdings will prefer less (or even no) hedging to increase the volatility of their option value due to the convexity of the option's payoff. It could be because of the beforementioned analysis which managers may use assumed interest rate hedging derivatives for speculation and gain more from the volatility of them instead of an instrument for risk management and volatility reduction. Finally, both institutional ownership and the number of analysts are higher for firms that do IR hedging, which show more institutional governance and less information asymmetry (more coverage of firm by analysts) could help firms to do more IR hedging and benefit their advantages.

We can do the same univariate analysis on dependent variables also to study the way IR hedging can impact the firm value and risk and resume to multivariate analysis and essential heterogeneity models estimations.

Table 4.5 shows that dependent variables are on average and median different between two groups of IR hedgers and non-hedgers as both t-test and chi-2 show significant differences between the two groups' mean and median. According to results presented in table 4.5, IR hedgers have lower firm value measured by Tobin's Q, higher ROE, lower idiosyncratic risks, higher systematic risk, more return sensitivity to oil future prices changes (higher oil beta), and lower sigma. In other words, less firm value motivates to do IR hedging and could result in better accounting performance, lower firm idiosyncratic risk where market risk is higher for hedgers which absolutely are more sensitive to future prices changes. Regarding crash risk, hedgers are riskier than non-hedgers in terms of mean and less risky on the median which shows hedgers were exposed to a wider range of crash risk in comparison with non-hedgers.

Table 4.5: Dependent variables statistical characteristic and univariate test by IR hedging

Variable	1. IR hedgers		2. non-IR hedgers		Comparison btw 1 and 2	
	Mean	Median	Mean	Median	t-stat	Pearson χ^2
Tobin's Q (in log)	1.400	1.296	1.784	1.485	15.652***	104.204***
Return on Equity	0.007	0.029	-0.021	0.025	-2.355**	5.080**
Idiosyncratic Risk	0.025	0.020	0.032	0.025	9.647***	70.505***
Systematic Risk	1.022	1.051	0.824	0.871	-7.283***	35.390***
Oil Beta	0.197	0.190	0.174	0.170	-2.385**	6.470**
Sigma (Volatility in equity)	0.505	0.419	0.579	0.472	5.957***	31.849***
Crash Risk	0.035	-0.048	-0.051	-0.095	-1.992**	5.011**

*Note: The superscripts ***, **, and * indicate statistical significance levels of 1%, 5%, and 10%, respectively.*

Now we can step forward to multivariate tests by doing our main regression of essential heterogeneity model by parametric estimation method. The next section will give a more precise analysis of the impact of IR hedging on firm value and risk (performance), average treatment effects (ATEs), and marginal treatment effects (MTEs) through causality results, plus the effect of control variables on firm performance.

4.4 Essential heterogeneity model estimation

For this part, we will resume our survey on the effect of IR hedging on firm value and risk by estimating our predominant model by parametric essential heterogeneity method as it was introduced in data and methodology chapters, in 2 steps including estimation of changes in Kilian index (as an instrumental variable) on IR hedging dummy (decisions of hedging or not-hedging) and then the effect of predicted (estimated from the first step) IR hedging on firm value and risk (TobinsQ as firm value, ROE as an accounting performance measure, and market risk, idiosyncratic risk, total risk, oil beta, and crash risk as firm risk features). We will include control variables in both steps.

Equation 4.1 shows the first step estimation in our 2step essential heterogeneity model regression that estimates changes in the Kilian index as an instrumental variable on the dummy variable of IR hedging.

Control variables in both steps (equations 4.1 and 4.2) include firm size, earning per share from operations, investment opportunities, leverage ratio, liquidity ratio, dummy variable of dividend payout, institutional ownership, oil reserves, geographic diversification of oil, oil production risk, oil spot price, oil price volatility, cash flow volatility, gas reserves, geographic diversification of gas production activities, gas production risk, gas spot price, gas price volatility, CEO stockholding, CEO option holding, and number of analysts who cover the firm.

$$(Interest\ Rate\ Hedging)_{i+1t} = \gamma_0 + \gamma_1 (Delta\ Kilian\ Index\ )_t + \\ + \sum_{j=2}^{M} \gamma_j (Control\ Variable)_{j,it} + V_{it} \qquad (4.1)$$

Equation 4.2 shows the second step of the essential heterogeneity model, showing the effect of predicted IR hedging on the outcome. The dependent variable could take the value of Tobin’s Q, ROE, idiosyncratic risk, systematic risk (market risk), oil beta, total risk (volatility or sigma), and crash risk.

$$(Firm\ value\ and\ risk)_{i+1t} = \alpha_0 + \beta_1 (predicted\ Interest\ Rate\ Hedging)_{it} + \\ + \sum_{j=2}^{N} \beta_j (Control\ Variable)_{j,it} + U_{it} \qquad (4.2)$$

Essential heterogeneity model estimation gives out two separate coefficient sets of control variables for treated and untreated groups. So, two models for IR hedgers and non-IR hedgers will be estimated which gives two different coefficients for control variables. Average treatment effect (ATE), the effect on unobservable components on IR hedging and so on firm value and risk, and marginal treatment effect (MTE) are also outcomes of our model. For this purpose, we estimate the parameters on the parametric method proposed by Anderson (2018) by using the *MTEFE* (Stata) command which is a more efficient, faster command in comparison with older commands like *MARGTE*. This command (*MTEFE*) also gives out more useful outcomes than previous versions in the results of the second step estimation which we will discuss in the following.

4.4.1 First-step: estimating instrumental variable on treatment

As we do the *MTEFE* command in Stata software, we can define software that gives out results on the first step by adding *first* at the end of the command and variables list. In this way, we can have the estimation of changes in the Kilian index as the instrumental variable on the IR hedging dummy defined as treatment in presence of some control variables as defined in the previous section for the first step.

We do regression of the choice equation by the probit model[5], gives us the estimation of the propensity score of doing IR hedging. The dependent variable is a dummy variable that takes the value of one for time and firm which does IR hedging and zero for non-IR hedged firm-quarters. All the independent variables (control variables and instrumental variable) in the first step regression are presented in the first lag. For more robustness, we will use clustering standard errors on firms (gvkey as firms code) and use the fixed-effect analysis provided by this command which could give out more precise results. The clustering will be useful for bootstrapping in the second step too.

As we use data in the first lag and some of the variables are missed for some oil producers, the model estimation is done (by fewer observations in comparison with the descriptive analysis section) in both stages using data on 129 firms and 4,211 observations (firm-quarters).

[5] . We can do logit or the linear probability model (LPM) for estimating the propensity score in the first step by using the command link(probit). As the only link function allowed in the parametric normal model is probit, if we become convinced to use other models, we have to use parametric polynomial or semiparametric polynomial models. Other empirical works show that the probit model works well for hedging decisions and is a far more efficient model also. So, we use the parametric method and prefer the probit model for the first step.

Table 4.6 presents the results of the first step regression and confirms the predictive power of Kilian index on IR hedging choice. The change in Kilian index coefficient is positive and statistically significant, suggesting that increasing change in aggregate demand for industrial commodities could result in higher prices for industrial commodities for oil producers too. This increases mobilization prices for using the investment opportunities for oil producers and in the same way, increases the need for external financing which may lead to the need to do IR hedging.

This effect of an increase in Kilian index is on the contrary with the traditional positive effect it could have on crude oil prices and derivative prices that could be translated to a decrease in hedging activities. Dionne and Mnasri (2018) show that the Kilian index is positively correlated with future prices. So, firms hedge less to take the benefits of increasing prices in future when the Kilian index is high and a negative coefficient of changes in Kilian index in hedging regression is observed. We obtain a positive coefficient which means that firms use more interest rate derivatives when the price of oil derivatives is high. So, we observe that financing needs overweighs this traditional effect and the positive effect of changes in Kilian index on IR hedging activities is shown.

Table 4.6 also presents other side results of the effect of control variables on IR hedging. We observe variables like leverage and oil reserves have statistically significant positive effects on IR hedging that is consistent with risk management theory, where gas production's geo-diversification has statically significant negative effect on IR hedging decisions. The negative effect of geographic diversification on IR hedging could be because of the fact that operational constraints motivate more IR hedging in oil producers. This variable's sign is consistent with the literature.

Table 4.6: First-step regression of the essential heterogeneity model; choice equation

Variable	Coefficient	Standard error	Z-value	P-value
Δ Kilian index	0.0007*	0.0004	1.66	0.097
Firm size (in log)	0.0739	0.1130	0.65	0.513
Earning per Share from operation	-0.0066	0.0174	-0.38	0.704
Investment opportunities	0.1731	0.1736	1	0.319
Leverage ratio	0.7908**	0.3280	2.41	0.016
Liquidity ratio	0.0037	0.0241	0.15	0.878
Dividend payout (0/1)	-0.1537	0.2074	-0.74	0.459
Institutional ownership	0.0639	0.2752	0.23	0.816
Oil reserves (in log)	0.1270*	0.0652	1.95	0.051
Geographic diversification of oil production	0.0229	0.3657	0.06	0.950
Oil production risk	0.0627	0.2665	0.24	0.814
Oil spot price	0.0001	0.0023	0.05	0.959
Oil price volatility	0.0184	0.0129	1.43	0.154
Cash flow volatility	-89.6947**	43.3678	-2.03	0.042
Gas reserves (in log)	0.0663	0.0781	0.85	0.396
Geographic diversification of gas production	-2.0457***	0.6009	-3.4	0.001
Gas production risk	-0.3660	0.2794	-1.31	0.190
Gas spot price	-0.0080	0.0179	-0.45	0.654
Gas price volatility	-0.0371	0.0432	-0.86	0.390
CEO stockholding	-1.3875	6.4549	-0.21	0.830
CEO option holding (*10,000)	0.0017	0.0013	1.24	0.215
Number of analysts	-0.0207	0.0165	-1.26	0.208
Constant	-2.1120***	0.5442	-3.88	0.000

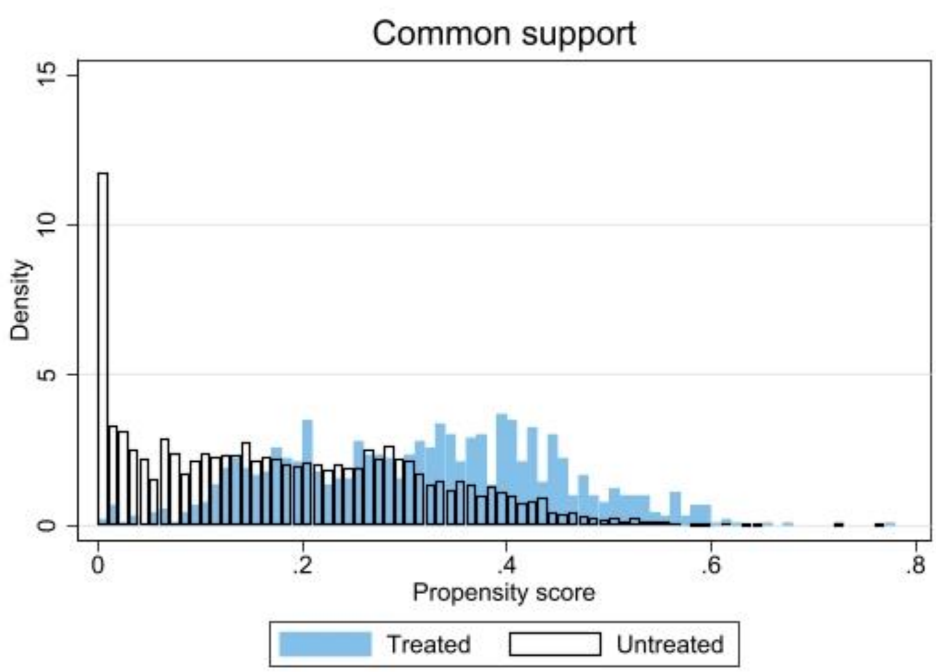
*Note: The superscripts ***, **, and *indicate statistical significance levels of 1%, 5%, and 10%, respectively. The number of observations is 4,211, Pseudo R-squared of the model is 0.1466, and the Log-likelihood of the model is -1848.897. Wald chi-squared is 94.31 and as the probability is 0.0000 so model is significant statistically.*

The only variable with statically significant sign that its sign is inconsistent with empirical works is cash flow volatility with a negative effect on IR hedging decisions. this sign could be because of the effect that IR hedging could have on decreasing cash flow volatility (reverse causality) or how oil producers use derivatives as an instrument for speculation and when the volatility of their cash flow increases, they switch to traditional safer hedging instruments and decrease the IR hedging.

MTEFE command in the first stage additionally gives out a common support plot which shows the distribution of propensity scores in the treated and untreated samples to visualize the common support.[6] These propensity scores will be used by software to calculate second step estimation, common treatment effects (ATE, ATUT, ATT, LATE…) calculations, and MTEs changes over unobserved resistance against treatment.

As in all estimations on outcomes of our models (Tobin's Q, ROE, and risks), the first step is common and the result on the first step is the same, so we have just one common support plot.

Figure 4.1: Propensity score distribution density for treated and untreated groups



[6] . If we use trimming limits on propensity score it could be considered in common support plot output.

Figure 4.1 is the common support plot of distribution (and density) of the treated group's propensity score in blue bars and propensity score density of the untreated group in white bars. According to our prediction, the bars that show the density of propensity scores (probability of being treated) which is distributed from zero to one are higher and more frequently present in lower propensity scores for untreated groups and the majority of firm-quarters in the untreated group have propensity score lower than 0.4 where propensity score distribution for the treated group is near to normal and the majority of treated firms have propensity score more than 0.1. The problem is just on untreated firm-quarters which have propensity scores more than 0.8 and treated ones with propensity scores less than 0.1, fortunately, these observations densities are so low.

Now we can continue to the second step of essential heterogeneity model estimation and the effect of prediction of doing IR hedging (treatment effect) on firms' value and risk measures to investigate how oil producers in our sample use IR hedging instruments? As a good risk management instrument? or just for speculation without significant effect on increasing firm value (or reducing firm risk) or even with a detrimental effect on firm value and risk?

4.4.2 Second-step: Firm value and accounting performance

Now we will proceed to the final results of estimation in the second stage. *MTEFE* command ignores the uncertainty in the estimation of the propensity scores, means of control variables(X), and the treatment-effect parameter weights by treating these as fixed in the second step of the estimation. These assumptions (especially the uncertainty in the propensity score), could increase the standard errors for the *ATE*, we should therefore bootstrap the standard errors using the *bootreps()* option, which re-estimates the propensity scores the mean of control variables in two groups of treated and untreated firm-quarters, and the treatment-effect parameter weights for each bootstrap repetition. We will estimate the model by 500 replications as repetitions for bootstrapping the standard errors.

MTEFE additionally can fit all models using either local IVs. Furthermore, it allows for fixed effects using Stata's categorical variables, which is important to isolate exogenous variation in many applications and provides gains in computational speed over generating dummies manually. *MTEFE* exploits the full potential of MTEs by calculating treatment effect parameters as weighted averages of the MTE curve, shedding light on why, for example, the LATE differs from the ATE. All of these outputs of command will be presented in tables of the second steps of our 6 outcomes.

Table 4.7 reports[7] the results of the outcome equation's estimation (estimation of equation 4.2) concerning firm value measurement which is Tobin's Q and firm accounting performance which is the return on equity (ROE). The output in the tables in this section (like table 4.7) gives the estimations for untreated groups (non-IR hedger firm-quarters) and the difference of the coefficients of control variables between treated and untreated groups.

Outcome tables in this section and the following sections (tables 4.7, 4.8, and 4.9) also indicate the inverse Mills ratio. Inverse Mills ratio is also marked as K is equal to $K_{treated} - K_{untreated} = \rho_1 - \rho_0$ which in equations 3.11 to 3.13 was defined as $\sigma_{v1} - \sigma_{v0}$ too. In other words, this term produces the essential heterogeneity by unobservable terms in the error term of treated and untreated firm-quarters in presence of specified resistance against treatment. This variable shows how the difference between propensity score of doing IR-hedging and propensity to non-inducement in doing IR-hedging (which is the term that causes the variation in MTE and changes MTE from a constant term to changing over different resistances) affect MTE. If inverse Mills ratio goes to zero, MTE goes to its traditional definition and constant over unobservable resistance (just could change over controls because of heterogeneity) and reject the existence of essential heterogeneity in our model and because of that inverse Mills ' p-value will be similar to essential heterogeneity test's p-value which will be introduced in following.

The average treatment effect (ATE), captures the expected average effect on outcome (firm value or risk) caused by becoming treated (do IR hedging) conditional on observable independent variables. In other words, ATE is the average difference between outcomes

[7] . To sum it up, for the whole estimation we used Stata routine *MTEFE* developed by Andresen (2018) to estimate the model of essential heterogeneity, our method was the parametric normal approximation of the MTE with 500 repetitions of bootstrapping the standard errors corrected for within-firm clustering.

(firm value or risk) of two groups of firm-quarters which are treated by receiving IR-hedging and non-hedged firm-quarters through observable variables in our model. The ATT is the average effect of treatment for the subpopulation that chooses treatment. The model gives more precise weight in calculating ATT to firm-quarters with high propensity scores because they have a higher probability of choosing treatment. Likewise, the weights ω_{ATT} will weight points at the lower end of the U_D distribution higher because a larger share of the population at these values of U_D will choose treatment, as they are facing lower quantities of unobservable resistance against doing IR hedging (being treated). In contrast, The ATUT is the average effect of treatment for the subpopulation that doesn't choose treatment. So, the model for calculating the ATUT weights individuals with low propensity scores higher because these firm-quarters, all else the same, have higher probability to be untreated, so high weights go for firm-quarters with high resistances (bigger U_D)

A LATE is the average effect of treatment for people who are shifted into (or out of) treatment when the instrument is shifted from treating situation produces propensity scores more than resistance to the situation which produces propensity score just lower than resistance and conversely. In other words, this estimated average difference in outcome (firm value or risk) for firm-quarters that their treatment assignment is sensitive to changes in Kilian index changes (the instrumental variable). So, this average treatment effect will be calculated on the population of firm-quarters with U_D which is in the interval of being and not being treated. When the difference between unobservable resistance (U_D) and propensity score (P_Z) is infinitesimally small, the LATE converges to the MTE, and an MTE is thus a limit form of LATE (Andresen, 2018).

In heterogeneity models, Stata calculates the PRTE for a counterfactual policy that manipulates propensity scores. PRTE shows the expected treatment effect for the firm-quarter that are shifted into treatment by the new policy relative to the baseline. If the policy is a particular set of instrument values, and the baseline is another set of instrumental variable’s quantity, the PRTE and LATE are the same. In practice, the PRTE parameter weights the treatment effect of firm-quarters that are affected more strongly by the alternative policy relative to the baseline. According to Carneiro, Heckman, and

Vytlacil (2010) by assuming policy invariance, command *MTEFE* calculates MPRTEs which are marginal policy-relevant treatment effects, and suggest three ways to define the distance to the margin. The first MPRTE, labeled MPRTE1 in the table, defines the distance between propensity score and the resistance by a marginal change in the instrumental variable in the first step. MPRTE2 defines the margin as having propensity scores close to the normalized resistance $U_D$and corresponds to a policy that would increase all propensity scores by a small amount. MPRTE3 defines marginal as the relative distance between the propensity score and U_D and corresponds to a policy that increases all propensity scores by a small fraction.

Lastly, the model gives two p-values on the test of the existence of observable heterogeneity and essential heterogeneity. The null hypothesis in both tests is the homogeneity of effects. The first statistical test is a joint test of the $\beta_1 - \beta_0$, which can be interpreted as a test of whether the treatment effect differs across control variables. If the p-value is over 0.1 it means the null hypothesis can't be rejected at the confidence level of 90 percent, so there will be observable heterogeneity which causes different treatment effects (effect of IR hedging on firm value and risk) over changes in control variables. The second test that is a test of essential heterogeneity is a joint test of all coefficients in unobserved resistances which affect propensity score and tests whether all MTEs are the same. This test's null hypothesis is that treatment effects are constant within mutually exclusive subgroups while allowing the treatment effects to vary across subgroups. So, if the p-value for this test is over 0.1 it means the null hypothesis can't be rejected at the confidence level of 90 percent, so there will be heterogeneity on treatment effects caused by unobservables and MTE will change over the different quantities of such resistance.

According to table 4.7, all the common treatment effects neither on treated group nor untreated are not statistically significant, meaning that there is no evidence that observable factors (control variables and IR-hedging) could influence differently firms' value and accounting performance (ROE). Between MPRTEs that are calculated for firm value and accounting performance, just MPRTE2 for accounting performance is statistically significant and positive indicates that if a policy (or any kind of change in situation from out of model) increases the tendency or desire of firms to do IR hedging (increase propensity score) on the firm-quarters that are very close to doing IR hedging (have propensity score a little bit above resistance against treatment or a little bit below) the margin (treatment effect) will significantly increase which means ROE will be positively impacted by such treatment.

Inverse Mills ratios of both estimations aren't significant showing that the MTE will not be affected by unobservables and it just could be variable over observable changes over presented variables. So, there is no essential heterogeneity in both models of estimating firm value and accounting performance, as is indicated by the test of essential heterogeneity p-value at the last cells of table 4.7. test on heterogeneity caused by observables indicate that just estimation on firm value suffers from observable heterogeneity and the ROE model is not exposed to any kind of heterogeneity.

Table 4.7: Second-step regression of the essential heterogeneity model; outcome equation(s)

Variables	Tobin's Q		ROE	
	β_0	$\beta_1 - \beta_0$	β_0	$\beta_1 - \beta_0$
Firm size (in log)	0.339*** (0.076)	-0.663* (0.401)	0.007 (0.0128)	-0.225 (0.153)
Earning per Share from operation	-0.0321 (0.021)	0.0957 (0.096)	0.0324** (0.015)	-0.0213 (0.054)
Investment opportunities	0.261 (0.414)	0.394 (1.415)	-0.004 (0.130)	-0.538 (1.052)
Leverage ratio	-0.232 (0.239)	4.172 (2.668)	-0.205*** (0.065)	-1.441 (1.302)
Liquidity ratio	0.0267* (0.015)	0.2470 (0.174)	0.0004 (0.001)	-0.0030 (0.072)
Dividend payout (0/1)	0.256** (0.113)	-0.931 (0.714)	0.060*** (0.019)	0.185 (0.276)
Institutional ownership	-0.787*** (0.146)	3.049*** (0.767)	0.045 (0.038)	-0.296 (0.272)
Oil reserves (in log)	-0.107*** (0.028)	0.391 (0.448)	0.002 (0.005)	-0.285 (0.218)
Geographic diversification of oil production	-0.306** (0.143)	0.388 (0.769)	-0.079 (0.053)	0.250 (0.343)
Oil production risk	0.187 (0.241)	-1.264 (1.233)	-0.006 (0.040)	-0.251 (0.317)
Oil spot price	0.0027 (0.002)	-0.0054 (0.009)	-0.0011* (0.0006)	0.0040 (0.0037)
Oil price volatility	-0.0476***	0.0751	-0.0095*	-0.0443

	(0.011)	(0.070)	(0.005)	(0.0316)
Cash flow volatility (/1000)	-0.0715*** (0.015)	-4.265 (4.250)	0.0021 (0.0026)	3.694* (1.901)
Gas reserves (in log)	-0.201*** (0.036)	0.640** (0.306)	0.003 (0.006)	-0.076 (0.126)
Geographic diversification of gas production	-0.258 (0.233)	-2.279 (6.803)	0.083 (0.070)	4.093 (3.352)
Gas production risk	0.568*** (0.207)	-1.521 (1.602)	-0.089* (0.0538)	1.138 (0.707)
Gas spot price	0.0622*** (0.018)	-0.0799 (0.091)	0.0211*** (0.005)	0.0054 (0.0393)
Gas price volatility	-0.055 (0.070)	-0.060 (0.424)	-0.026 (0.018)	0.101 (0.131)
CEO stockholding	8.081*** (2.912)	-21.870 (14.25)	-1.557 (1.136)	-4.583 (7.397)
CEO option holding (*10,000)	-0.0029*** (0.0011)	0.0108** (0.0048)	0.0002 (0.0003)	-0.0025 (0.0026)
Number of analysts	0.0015 (0.009)	-0.0119 (0.083)	-0.0010 (0.0027)	0.0442 (0.038)
Constant	0.454** (0.197)	-9.117 (10.91)	0.0205 (0.041)	7.157 (5.337)
Inverse Mills ratio	-5.896 (5.205)		3.334 (2.462)	
ATE	-9.063 (8.493)		6.252 (4.120)	
ATT	0.641 (0.799)		0.0930 (0.210)	
ATUT	-11.670 (10.84)		7.906 (5.225)	
LATE	-2.814 (779.4)		2.024 (70.35)	
MPRTE1	-2.857 (2.975)		2.164 (1.494)	
MPRTE2	-3.884 (4.151)		3.323* (2.004)	
MPRTE 3	-6.411 (6.395)		4.838 (3.105)	
Test of observable heterogeneity, p-value	0.0000		0.7764	
Test of essential heterogeneity, p-value	0.2573		0.1757	
Observations	4,211	4,211	4,211	4,211

*Note: Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1*

Now we can proceed with the control variables' effect on firm value and accounting performance in the untreated group and the distinction between treated and untreated ones in terms of coefficients of control variables. Table 4.7 shows that firm size, institutional ownership, gas reserves, and CEO option holding are significantly related to Tobin's q for the untreated group and significantly have different effects on Tobin's q of IR hedgers and non-IR hedgers. institutional ownership, gas reserves, and CEO option holding all negatively affect the firm value for non-hedgers which could be because firms with more natural resources and opportunities to benefit from fluctuation which don't have appropriate risk management actions and don't do IR hedging will expose bigger risks which could affect their value negatively, but when they do IR hedging the effect of firm size on firm value become positive which shows become treated and do IR hedging will positively increase the effect of firm size on Tobin's q.

Firm size has significant positive effect on non-hedgers' firm value but going to IR-hedging will reduce the effect of firm size on firm value even to a negative quantity. So, by doing IR hedging, bigger firms will lose firm value, it could be because bigger firms by doing IR hedging will reduce the investment opportunities and constraint their resources that will affect negatively their value where smaller firms that do IR hedging could gain more benefits from overcoming risks and cash flow fluctuations and so, it positively affects their value.

Liquidity ratio, dividend payouts, gas production risk, gas spot price, and CEO stockholding positively impact Tobin's q for non-hedger firm-quarters or maybe IR hedgers but there is no statistically significant difference in these variables' effects on Tobin's q between IR hedgers and non-hedgers. Positive effects of variables liquidity ratio, dividend payouts, gas spot price, and CEO stockholding on Tobin's q which increase firm value are consistent with the literature and previous empirical works. The positive effect of gas production risk on non-hedger oil producers could be because of investors' decision to compensate the non-hedgers more because these firms allow investors to take the advantage of upward volatilities of gas prices, although it affects negatively ROE of non-hedgers. Between these variables, dividend payouts, gas spot price positively affect ROE in the same way they have an impact on firm value.

On the other hand, oil reserves, geographic diversification of oil, oil price volatility, and cash flow volatility negatively impact Tobin's q for non-hedgers without any evidence on having a different effect on firm value through hedgers and non-hedgers. The firms with more oil reserves are more exposed to the risk of fluctuations in the market so for non-hedgers an increase in oil reserves will increase firm risk and decrease its value. Oil price volatility's negative effect on Tobin's q could also justify with its direct correlation with risk and negative effect on firm value, where we can approach geographic diversification negative effect on firm value as technical constraints of working in separate sites which makes it hard for investors to continuously cover firm's activity and sometimes underestimate its worth. Additionally, oil price volatility also has a negative effect on ROE (firm accounting performance) because of the same reason for affecting firm value.

Importantly, cash flow volatility negatively affects firm value which is completely consistent with literature where it increases firm risk and underinvestment and overinvestment problems simultaneously in firms (especially non-hedgers). When it comes to ROE, cash flow volatility could affect differently the ROE of hedgers and non-hedgers by a positive difference it gives to IR-hedgers which means if firms do IR-hedging because some risk of fluctuation in cash flow volatility have been hedged now cash flow volatility can positively affect firm performance and hedgers could benefit from it.

Table 4.7 further shows that leverage ratio and oil spot price have negative significant effects on firm's accounting performance (ROE) for the untreated group. The negative effect of leverage ratio on ROE could be because when leverage ratio increases default probability goes up and financial distress will increase for non-hedgers which don't use the benefits of risk management so they experience a decrease in ROE, where negative effect of oil price on ROE is not consistent with the literature. Finally, EPS positively impacts ROE for non-hedgers which is consistent with literature where no evidence on different effects on ROE of IR-hedgers and non-IR hedgers is reported by the table.

Now we can proceed to analyze the MTEs for Tobin's q and ROE considering unobservables (non-observables) which produce a distinction between firms with almost the same observable variables. We assume that all firms aren't homogenous (concerning unobserved factors) in deriving an average IR-hedging effect on firm value. Marginal treatment effect (MTE) may differ between firms that have to be categorized in either group (IR-hedgers and non-hedgers) by adding the possibility of self-selection explained by unobservables.

Figure 4.2: Estimated MTEs over the common support of unobservable resistance against treatment for Tobin's q

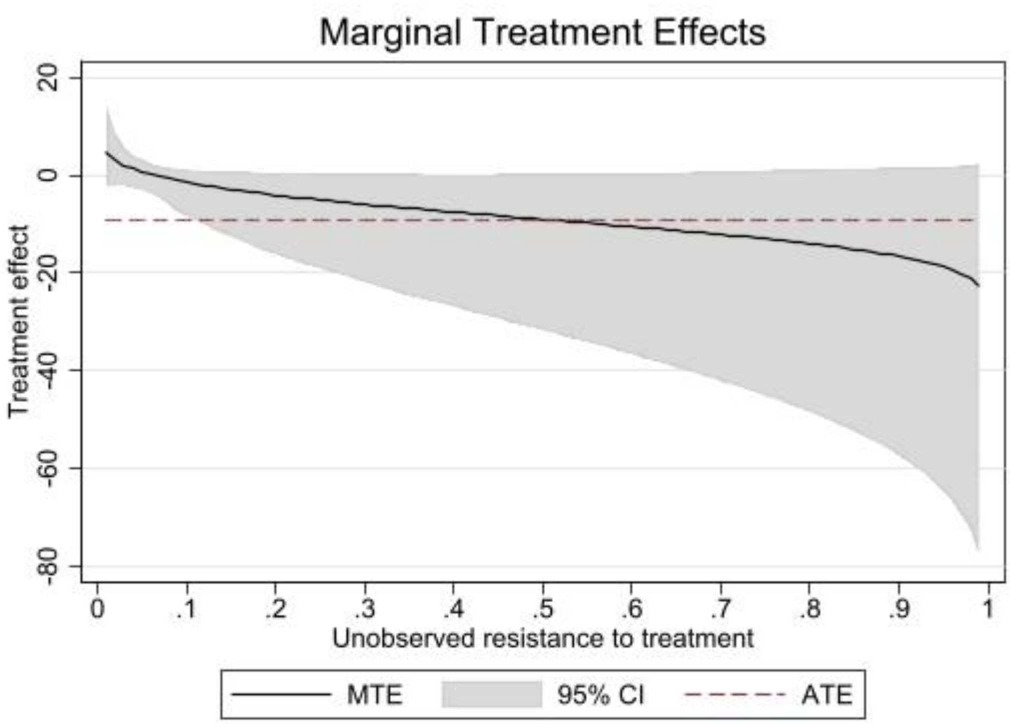


Figure 4.2 reports the estimated MTEs on Tobin's q with 95% confidence intervals, evaluated at the means of the independent (observable) variables over different quantiles of the unobserved resistance to do IR-hedging (U_D). The ATE is also plotted (dashed line) as a reference point. Figure 4.2 shows that estimated MTEs on Tobin's q are decreasing with different quantiles of unobservable resistance against IR hedging, implying that more return goes for firm-quarters which are more likely to do IR-hedging that have lower resistance against being treated (lower unobservable resistance against IR hedging). So, the marginal Tobin's q is higher for oil producers that are more likely to do IR hedging as firms choose IR hedging in which they have comparative advantages. The figure shows

that estimated MTEs range from a return of 5% for firm-quarters with the highest propensities for doing IR-hedging (lowest U_Ds) to roughly -25% for those with propensity scores near 0 ($U_D$near to 1.0).

Moreover, the exact number of estimated MTEs for different evaluation quantile points of U_D, from 0.01 to 0.99 on firm value, accounting performance, and risk with standard errors are reported in tables presented in appendix B. Estimated MTEs in the lower percentiles are positive and statistically significant. Table B.1 shows that although the estimated MTEs which show returns are not statistically significant, they vary from 4.65% for observations with lower resistances that have higher propensity scores to be treated and using IR hedging instruments to -22.78% for firm-quarters that are more likely to don't do IR hedging because of high resistance to do treatment and lowest propensity score they have. Overall, our results show that marginal return (firm value) increases with the propensity to use IR-hedging which is consistent with the literature.

Figure 4.3: Estimated MTEs over the common support of unobservable resistance against treatment for ROE

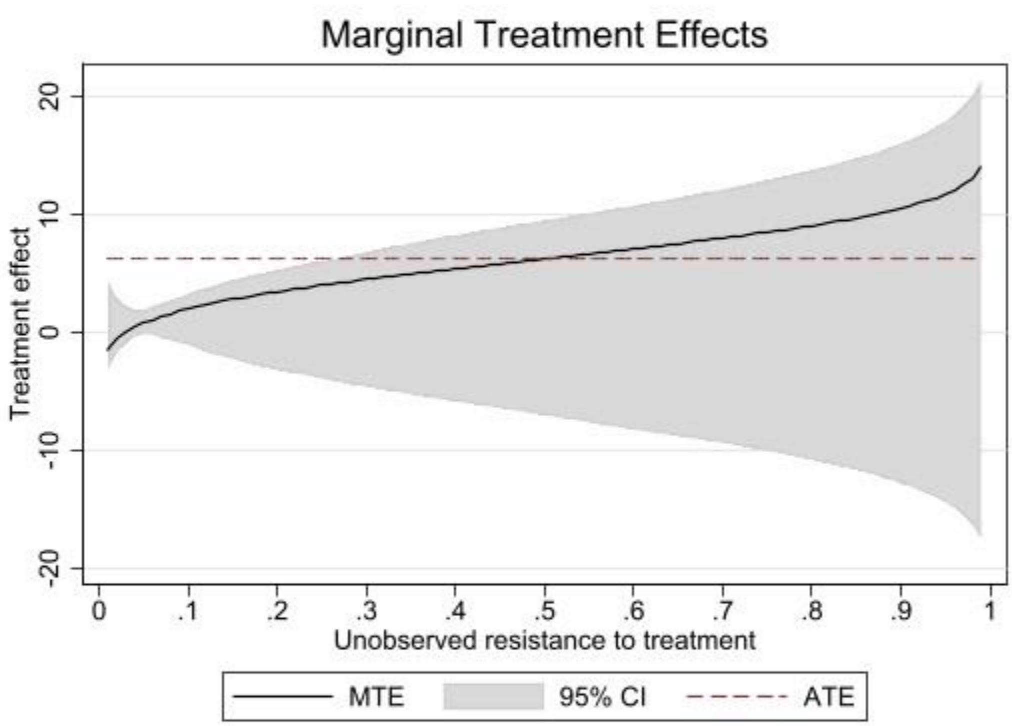


Figure 4.3 reports the estimated MTEs on ROE with 95% confidence intervals over the unobserved resistance to do IR-hedging (U_D). According to the figure estimated MTEs on ROE are increasing with unobservable resistance against IR hedging, implying that more return goes for firm-quarters which are less likely to do IR-hedging (higher U_Ds). Estimated MTEs range from a return of roughly -1% for firm-quarters with the highest propensities for doing IR-hedging (lowest U_Ds) to about 14% for those with propensity scores near 0 ($U_D$near to 1.0).

Table B.2 shows that although the estimated MTEs vary from -1.50% for firm-quarters with lowest resistances that have higher propensity scores to 14.01% for firm-quarters that are more likely to don't do IR hedging. Moreover, MTEs are statistically significant just for the sixth quartile till the twenty-first quantile of unobservable resistance in the range of 1.07% to 3.56% which corresponds to firm-quarters that have relatively bigger propensity scores and are more likely to do IR-hedging.

This significant MTEs over unobservable resistance is calculated for first quantiles which indicate firm-quarters with lower resistance against being treated or in other words for firm-quarters which are more likely to do IR hedging. So, table B.2 shows that oil producers with low resistance to IR hedging statistically have significant higher ROE and better accounting performance.

4.4.3 Second-step: Idiosyncratic risk, systematic risk, total risk

Now we study the estimation on risk factors including idiosyncratic risk, systematic risk (market risk), and sigma implying whole volatility or total risk. The first step which is the estimation of IR-hedging on a bunch of control variables and instrumental variables (changes in Kilian index) is the same as before and just the second step is different from the estimation of firm value and accounting performance discussed in the previous section.

According to table 4.8 inverse Mills ratios of estimations aren't significant showing that the MTE will not be affected by unobservables. So, the essential heterogeneity is not present in models, as it is indicated by the test of essential heterogeneity p-value at the last cells of table 4.8. Test on heterogeneity caused by observables indicates that all estimations on firm risk suffer from observable heterogeneity. With the explanation that the total risk (sigma) model has observable heterogeneity just on 10% significance level. Moreover, all the common treatment effects are not statistically significant. MPRTEs that are calculated for firm risk measures are also insignificant indicating that we can't define any change in policy or small (quantity or ratio) change in propensity score or instrumental variable which could affect marginal output (firm risk).

Regarding the control variables' effect on firm risk in the untreated group and the distinction between treated and untreated, table 4.8 shows that firm size, dividend payout, and investment opportunities have negative effects on oil producers' idiosyncratic and total risk. These results are consistent with the literature. Additionally, dividend payout has a negative effect on the market risk of oil producers too, firm size has different effects on the market risk of IR hedgers and non-IR hedgers, and doing hedging will reduce firm systematic risk even more than when the firm was not IR-hedged. Institutional ownership has a negative significant effect on non-hedger oil producers' idiosyncratic risk, but it positively affects their systematic risk, but when firms go to IR hedging this effect on market risk will reduce and become negative which is evidence of the fact that institutional ownership in presence of IR-hedging could reduce oil producers' market risk.

Table 4.8: Second-step regression of the essential heterogeneity model; idiosyncratic, systematic, and total risk equations

Variables	Idiosyncratic risk		Systematic risk		Sigma (Total risk)	
	β_0	$\beta_1 - \beta_0$	β_0	$\beta_1 - \beta_0$	β_0	$\beta_1 - \beta_0$
Firm size (in log)	-0.0069*** (0.0009)	0.0098 (0.0077)	0.0618 (0.045)	-0.4710* (0.262)	-0.1020*** (0.016)	0.1560 (0.173)
Earning per Share from operation	1.10e-05 (0.0007)	-0.0014 (0.0026)	0.0007 (0.0294)	0.0373 (0.107)	0.0011 (0.013)	-0.0274 (0.053)
Investment opportunities	-0.0079** (0.004)	0.0249 (0.030)	0.146 (0.190)	-0.611 (1.287)	-0.1280** (0.064)	0.482 (0.653)
Leverage ratio	0.0025 (0.0032)	0.0839 (0.0753)	-0.121 (0.166)	-1.144 (2.325)	0.0333 (0.0511)	1.860 (1.727)
Liquidity ratio	1.09e-05 (0.0001)	0.0011 (0.0036)	0.00213 (0.0085)	-0.0400 (0.1660)	-0.0003 (0.0027)	0.0241 (0.0793)
Dividend payout (0/1)	-0.0095*** (0.0014)	0.0185 (0.0170)	-0.237*** (0.0743)	0.730 (0.515)	-0.161*** (0.0270)	0.203 (0.387)
Institutional ownership	-0.0055** (0.0022)	0.0010 (0.0144)	0.667*** (0.116)	-1.974*** (0.608)	-0.0484 (0.039)	-0.0234 (0.309)
Oil reserves (in log)	-1.26e-05 (0.0004)	0.0083 (0.0129)	0.0167 (0.0234)	-0.191 (0.404)	-0.0019 (0.0068)	0.243 (0.299)

Geographic diversification … oil	0.0058** (0.0027)	-0.0129 (0.0167)	0.0288 (0.168)	0.332 (0.701)	0.0827* (0.044)	-0.180 (0.366)
Oil production risk	0.0047** (0.002)	-0.0102 (0.016)	-0.103 (0.120)	-0.139 (0.715)	0.0718** (0.033)	-0.161 (0.341)
Oil spot price	-3.31e-05 (3.37e-05)	0.0001 (0.0002)	-0.0003 (0.001)	0.0065 (0.007)	-0.0002 (0.0006)	0.0048 (0.004)
Oil price volatility	0.0025*** (0.0003)	-0.0019 (0.0019)	0.0381*** (0.0136)	-0.110* (0.0654)	0.0528*** (0.0063)	0.0088 (0.0414)
Cash flow volatility (/1000)	0.0016*** (0.004)	0.096 (0.105)	0.039 (0.024)	0.6682 (3.434)	0.0239*** (0.007)	0.7735 (2.340)
Gas reserves (in log)	0.0014*** (0.0004)	0.0005 (0.0077)	0.0456** (0.0225)	-0.0623 (0.261)	0.0186*** (0.0069)	0.0809 (0.175)
Geographic diversification … gas	0.0048 (0.0046)	-0.0861 (0.193)	0.335 (0.239)	0.162 (5.798)	0.0859 (0.076)	-3.014 (4.486)
Gas production risk	0.0041** (0.0017)	-0.0317 (0.0392)	0.100 (0.109)	0.455 (1.189)	0.0754** (0.030)	-0.793 (0.906)
Gas spot price	-0.0005 (0.0003)	-0.0018 (0.0019)	-0.0311** (0.0156)	0.167** (0.0728)	-0.0121** (0.006)	-0.0495 (0.042)
Gas price volatility	0.0002 (0.0013)	0.0037 (0.0074)	0.0489 (0.067)	-0.0862 (0.298)	0.0149 (0.025)	0.166 (0.166)
CEO stockholding	0.0635 (0.068)	-0.331 (0.376)	4.271 (4.043)	-21.26 (17.40)	0.901 (1.145)	-6.701 (8.021)
CEO option holding (*10,000)	8.82e-06 (2.55e-05)	0.0001 (0.0001)	-0.0004 (0.001)	0.0003 (0.0057)	0.0001 (0.0004)	0.0031 (0.0035)
Number of analysts	0.0005*** (0.0001)	-0.0020 (0.0022)	0.0036 (0.008)	-0.0091 (0.067)	0.0117*** (0.002)	-0.0577 (0.0504)
Constant	0.061*** (0.003)	-0.211 (0.305)	0.0349 (0.167)	9.327 (8.925)	0.931*** (0.052)	-5.459 (7.070)
Inverse Mills ratio	-0.0678 (0.142)		3.386 (4.212)		-2.067 (3.259)	
ATE	-0.0577 (0.235)		5.030 (6.886)		-2.604 (5.441)	
ATT	0.0066 (0.0131)		-0.192 (0.620)		0.102 (0.223)	
ATUT	-0.0748 (0.298)		6.430 (8.750)		-3.328 (6.896)	
LATE	-0.0025 (14.31)		2.272 (362.1)		-0.549 (362.8)	
MPRTE1	-0.0355 (0.0857)		1.892 (2.488)		-1.177 (2.000)	
MPRTE2	0.0019 (0.113)		2.055 (3.356)		-0.788 (2.625)	
MPRTE 3	-0.0236 (0.176)		3.493 (5.199)		-1.630 (4.086)	
Test of observable heterogeneity, p-value	0.0004		0.0000		0.0635	
Test of essential heterogeneity, p-value	0.6325		0.4215		0.5259	

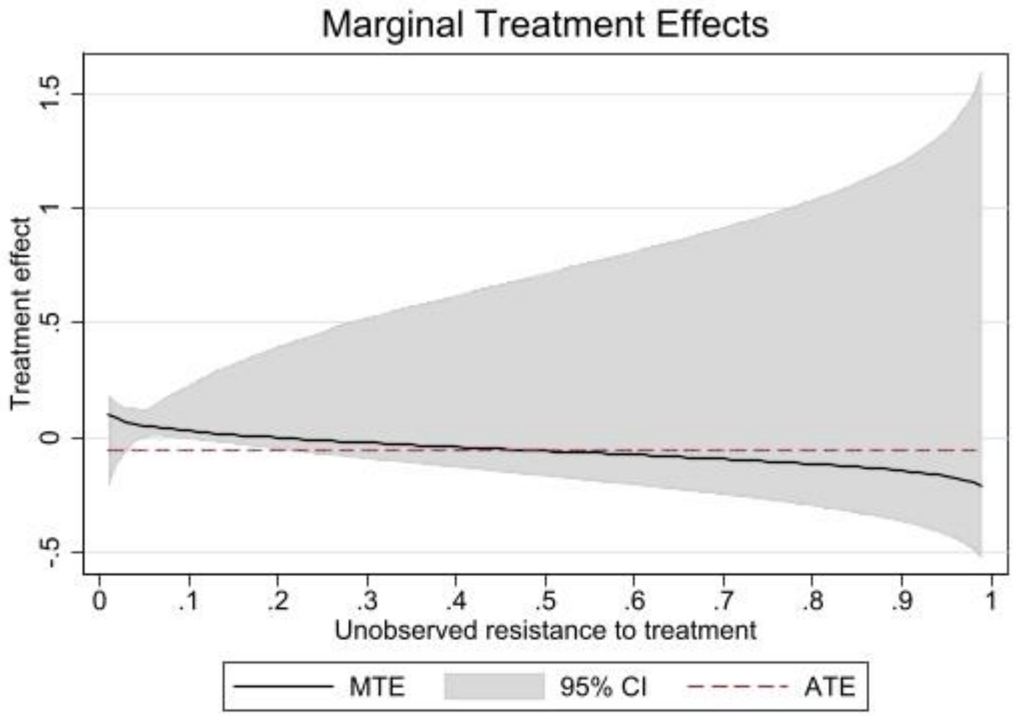
*Note: Standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1*

As table 4.8 indicates, geographic diversification of oil, oil production risk, oil price volatility, gas production risk, and cash flow volatility positively impact idiosyncratic risk and total risk for non-hedgers without any evidence on having a different effect on firm value through hedgers and non-hedgers. These results are consistent with the literature as discussed in the previous section. Oil price volatility additionally has positive effect on the market risk of non-hedgers, where its effect on hedgers is significantly different where IR-hedging will reduce the market risk associated will an increase in oil price volatility. Gas reserves significantly has positive effect on non-hedgers' idiosyncratic, systematic and total risk which is consistent with the results on firm value and could be because of the bigger risk that oil producer with more resources will face when they don't do IR hedging.

Gas spot price negatively impacts oil producers' systematic risk and total risk for non-hedgers and statistically significant difference in effects on systematic risk of IR hedgers and non-hedgers. The positive effect of gas spot price on the market risk of oil producers that do IR-hedging could be because of losing opportunities of upward changes in gas market prices which increase hedgers' risk. Lastly, the number of analysts has a significant positive effect on firms' idiosyncratic and total risk just for non-hedgers where it becomes negative for hedgers although the coefficient is not significant.

Figure 4.4 gives out the estimated MTEs on the idiosyncratic risk of oil producers with 95% confidence intervals over the unobserved resistance to do IR-hedging (U_D). MTE is decreasing with unobservable resistance against IR hedging, implying that more return goes for firm-quarters which are more likely to do IR-hedging that have lower resistance against being treated (lower unobservable resistance against IR hedging). Figure shows that estimated MTEs range from a return of 0.1% for firm-quarters with the highest propensities for doing IR-hedging (lowest U_Ds) to roughly -0.15% for those with propensity scores near 0 ($U_D$near to 1.0).

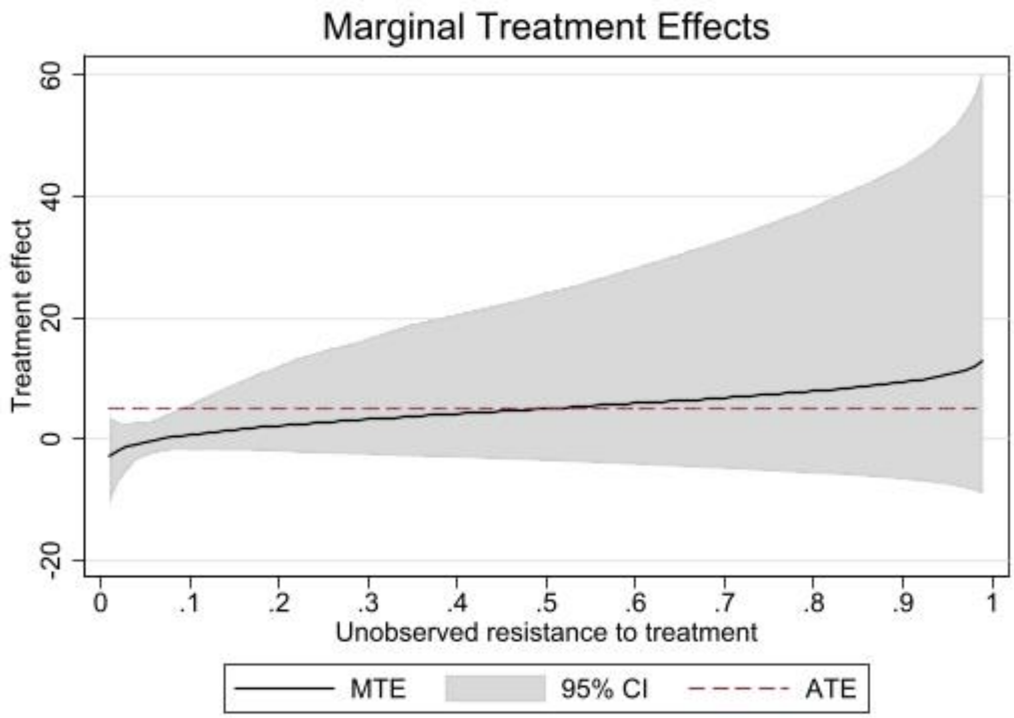
Figure 4.4: Estimated MTEs for idiosyncratic risk



Moreover, the exact number of estimated MTEs for different evaluation quantile points of U_D, from 0.01 to 0.99 for idiosyncratic risk is presented in table appendix B.3 showing that estimated MTEs just in the 4^{th} and 5^{th} percentiles are positive and statistically significant on around 0.061 and 0.54 percentages of MTE.

Figure 4.5 reports the estimated MTEs on systematic risk with 95% confidence intervals over the unobserved resistance to do IR-hedging (U_D). According to figure estimated MTEs on systematic risk are increasing with unobservable resistance against IR hedging, implying that more return goes for firm-quarters which are less likely to do IR-hedging (higher U_Ds), or in other words, the oil producers which are more likely to do IR-hedging (have higher propensity score, lower resistance against being treated) have lower systematic risk. According to figure and Table B.4 estimated MTEs range from a return of roughly -2.84% for firm-quarters with the highest propensities for doing IR-hedging (lowest U_Ds) to about 12.91% for those with propensity scores near zero (highest unobservable resistance: U_{99}). Although the results are consistent with the literature and our prediction on the effect of IR-hedging on reducing firms' market risk, MTEs are not statistically significant (like the effect on Tobin's q).

Figure 4.5: Estimated MTEs for systematic risk



The last MTE changes over unobservables resistance in this section for total risk is presented in figure 4.6. According to the figure, MTE on total risk is decreasing with unobservable resistance against IR hedging, implying that more the oil producers with more propensity scores which are more likely to do IR hedging are facing higher total risk. This result is inconsistent with literature and previous empirical works on hedging activities, although the fact that according to table B.5 in appendix B the estimated MTEs for quantiles of $U_D$are not statistically significant. this could be because of speculation incentives that entice oil producers to use IR-hedging instruments as a speculation instrument and not for risk management purposes.

Figure 4.6: Estimated MTEs for total risk

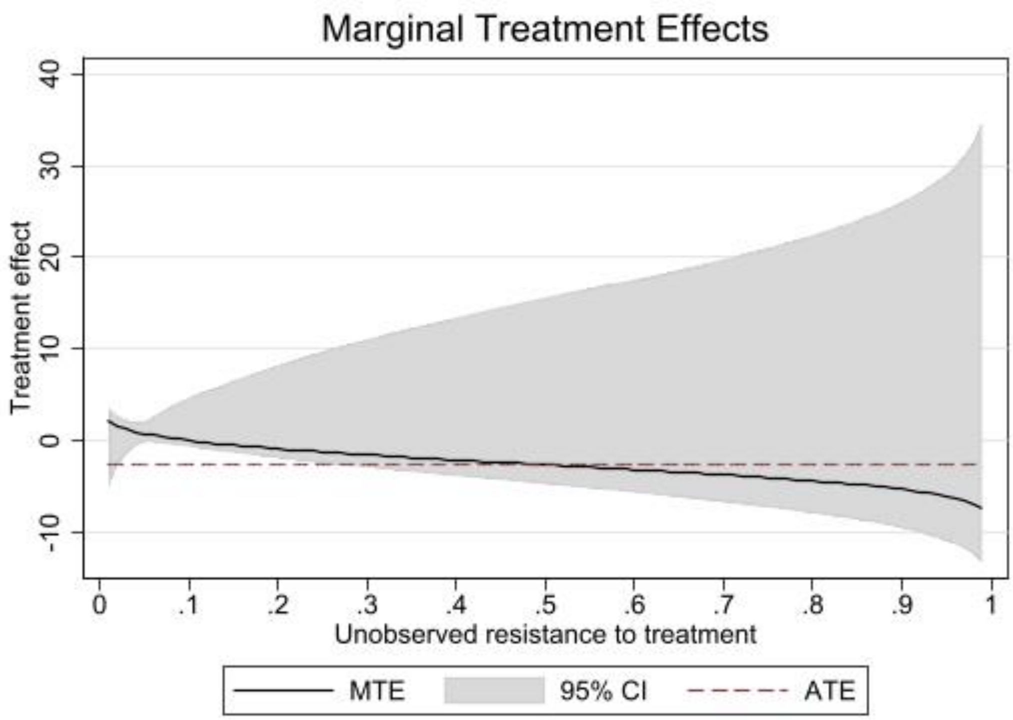


Table B.5 shows that although the estimated MTEs vary from 2.20% for firm-quarters with lowest resistances that are more likely to do IR-hedging to -7.41% for firm-quarters with the lowest propensity score that are more likely to don't do IR hedging.

4.4.4 Second-step: Oil beta and Crash risk

Now we can wrap up this chapter by analyzing the estimation of oil beta and crash risk of oil producers. The first step which is the estimation of IR-hedging on a bunch of control variables and instrumental variable (changes in Kilian index) is the same as before and table 4.9 gives out the results for the estimation of predicted IR hedging and a bunch of control variables over oil beta and crash risk.

Table 4.9 demonstrates that inverse Mills ratios showing essential heterogeneity, or effect of unobservables on MTE), all the common treatment effects (ATE, ATUT, ATT, and LATE), and even MPRTEs are not statistically significant. The same result was shown in table 4.8 in terms of idiosyncratic, systematic, and total risk. So, there is no evidence on the significant effect of IR hedging on oil beta and crash risk plus, no change in policy or small (quantity or ratio) change in propensity score or instrumental variable could affect marginal output. Also, the p-value of the test of essential heterogeneity shows that there is no essential heterogeneity in our model and confirms the same result we find about inverse Mills ratio like previous risk factors results. Test on heterogeneity caused by observables indicates that the estimation model of oil beta suffers from observable heterogeneity. But crash risk estimation's heterogeneity test indicates that there is no observable heterogeneity in the model. So, the crash risk estimation model is homogeneous in terms of observables and unobservables.

Additionally, we can analyze the control variables' effect on oil beta and firm crash risk in the untreated group and the distinction between treated and untreated as is reported in table 4.9. Firm size has a statistically significant effect on non-IR hedgers' oil beta and crash risk contrary to the effect which it has on firm idiosyncratic and systematic risk. It could be because bigger non-hedgers are more exposed to be sensitive to oil price changes (bigger oil beta) and more vulnerable to fluctuations in the market which increase their crash risk. But dividend payout has a negative effect on oil beta for non-IR hedgers like the effect it has for firm risks in the previous section. Oil production risk and oil price volatility negatively affect crash risk which is inconsistent with the literature. The oil spot price has a positive effect on oil beta for non-hedgers which could be because of higher sensitivities of oil producers on oil price in a higher price in terms of they are deprived of hedging activities.

Cash flow volatility has no significant effect on oil producers' oil beta and crash risk neither on IR-hedgers nor non-hedgers. Gas reserves has a negative effect on non-hedgers oil beta which is consistent with the literature as big reserves owners are less sensitive to changes in oil price.

Table 4.9: Second-step regression of the essential heterogeneity model; Oil beta and Crash risk

Variables	Oil beta		Crash risk	
	β_0	$\beta_1 - \beta_0$	β_0	$\beta_1 - \beta_0$
Firm size (in log)	0.035** (0.016)	-0.136 (0.117)	0.114* (0.059)	-0.081 (0.429)
Earning per Share from operation	-0.0095 (0.010)	0.0276 (0.034)	0.0647 (0.056)	-0.1160 (0.151)
Investment opportunities	0.063 (0.075)	-0.201 (0.536)	-0.363 (0.484)	0.443 (2.070)
Leverage ratio	0.100 (0.086)	0.072 (1.048)	-0.059 (0.172)	-1.747 (3.305)
Liquidity ratio	0.0015 (0.002)	0.0036 (0.051)	-0.0042 (0.010)	-0.0701 (0.127)
Dividend payout (0/1)	-0.0643*** (0.024)	-0.0121 (0.244)	0.2100 (0.128)	0.0206 (0.855)
Institutional ownership	-0.038 (0.038)	0.254 (0.211)	0.150 (0.178)	-0.551 (0.876)
Oil reserves (in log)	0.0009 (0.009)	0.124 (0.181)	-0.0189 (0.0195)	-0.125 (0.518)
Geographic diversification of oil production	-0.009 (0.060)	0.104 (0.263)	-0.218 (0.173)	-0.118 (0.868)
Oil production risk	-0.033 (0.048)	0.243 (0.283)	-0.215* (0.123)	0.019 (0.821)
Oil spot price	0.0027*** (0.0005)	-0.0027 (0.0028)	-0.00247 (0.0017)	-0.0144 (0.0092)
Oil price volatility	0.0020 (0.0037)	-0.0146 (0.0245)	-0.0253** (0.0109)	0.0340 (0.0775)
Cash flow volatility (/1000)	0.0005 (0.007)	0.099 (1.583)	-0.0016 (0.014)	-2.656 (4.524)
Gas reserves (in log)	-0.0198*** (0.007)	0.133 (0.110)	-0.001 (0.020)	-0.419 (0.317)
Geographic diversification of gas production	0.0067 (0.092)	-1.636 (2.798)	-0.034 (0.229)	2.100 (8.106)
Gas production risk	-0.0622* (0.033)	0.0316 (0.525)	0.0900 (0.155)	0.5920 (1.705)
Gas spot price	-0.004 (0.006)	0.006 (0.031)	0.014 (0.017)	0.179* (0.097)
Gas price volatility	0.0171 (0.024)	-0.100 (0.116)	0.0444 (0.068)	-0.0520 (0.382)
CEO stockholding	-0.167 (1.238)	-1.458 (5.681)	3.327 (3.202)	-9.088 (16.570)
CEO option holding (*10,000)	0.0002 (0.0004)	0.0005 (0.0021)	6.17e-05 (0.0014)	-0.0019 (0.0063)
Number of analysts	0.0088*** (0.002)	-0.0337 (0.0301)	0.0033 (0.012)	0.0426 (0.102)

Constant	-0.0967* (0.055)	-0.530 (4.328)	-0.598*** (0.188)	6.891 (13.30)
Inverse Mills ratio	-0.353 (2.016)		2.556 (6.135)	
ATE	-0.772 (3.357)		2.226 (9.994)	
ATT	-0.269 (0.248)		-0.460 (0.727)	
ATUT	-0.906 (4.263)		2.942 (12.71)	
LATE	-0.443 (198.60)		0.787 (351.4)	
MPRTE1	-0.519 (1.218)		1.062 (3.596)	
MPRTE2	-0.462 (1.652)		-0.020 (4.745)	
MPRTE 3	-0.630 (2.547)		0.945 (7.438)	
Test of observable heterogeneity, p-value	0.0019		0.3804	
Test of essential heterogeneity, p-value	0.8611		0.6769	
Observations	4,211	4,211	4,211	4,211

*Note: Standard errors in parentheses, and *** p<0.01, ** p<0.05, * p<0.1*

Table 4.9 shows also that the difference between coefficients of the gas spot price for IR-hedgers and non-IR hedgers is positive where an increase in gas prices will increase crash risk of hedgers more than non-hedgers because of the behavior of investors which show lower interest to hedgers shares that deprive them of positive fluctuations in the gas market. Number of analysts has a significant positive effect on oil beta just for non-hedgers like the effect on idiosyncratic risk, where it becomes negative for hedgers although the coefficient is not significant.

Figure 4.5 shows the estimated MTEs on oil beta with 95% confidence intervals over the unobserved resistance to do IR-hedging (U_D). MTE is decreasing with unobservable resistance against IR hedging, which means that firm-quarters with lower resistance against being treated that are more likely to do IR-hedging have more oil beta. This plot is descending from approximately 0.04 for firm-quarters with the highest propensities for doing IR-hedging (lowest U_Ds) to -1.6 for $U_D$near to 1.0. more precise results for MTEs over unobservable resistance is given in appendix B.6 for different evaluation quantile points of U_D, from 0.01 to 0.99 showing that although the fact that estimated MTEs are decreasing over U_D from 0.048 to -1.59 but all of the estimated MTEs are statistically insignificant.

Figure 4.7: Estimated MTEs for oil beta

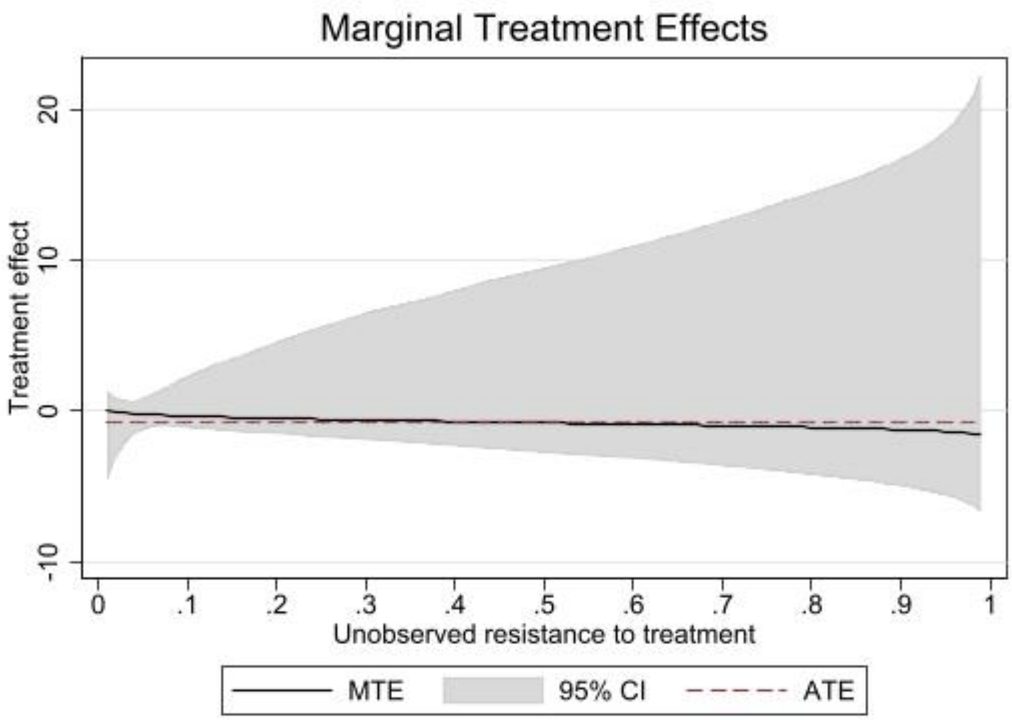
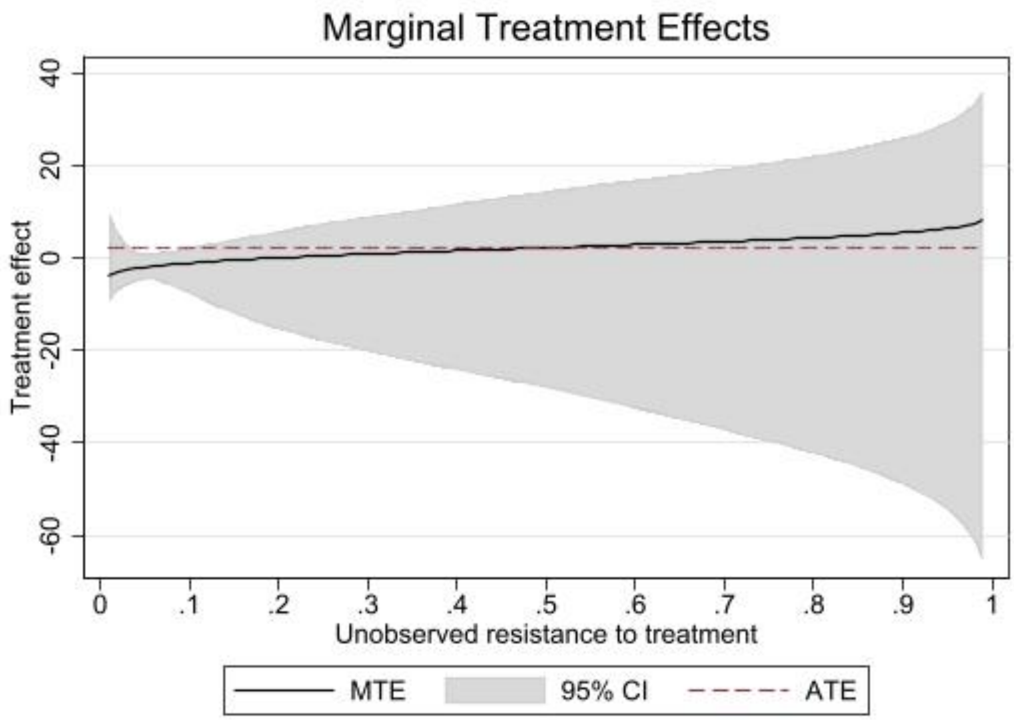


Figure 4.8 reports the estimated MTEs on crash risk with 95% confidence intervals over the unobserved resistance to do IR-hedging (U_D). Consistent with our prediction, estimated MTE on crash risk is increasing with unobservable resistance against IR hedging, implying that the oil producers which are more likely to do IR-hedging (have higher propensity score, lower resistance against being treated) experience lower crash risk. According to Table B.7 estimated MTEs range from a return of roughly -3.72% for firm-quarters with the highest propensities for doing IR-hedging (lowest U_D) to about 8.17% for those with propensity scores near zero (highest unobservable resistance U_{99}). Although the results are consistent with literature and confirm the effect of IR-hedging on reducing firms' crash risk, MTEs are not statistically significant (like the positive effect of IR-hedging on Tobin's q and negative effect of IR-hedging on firm systematic risk).

Figure 4.8: Estimated MTEs for crash risk



In the next chapter which is the last chapter of this essay, we will summarize the results of our model and their analysis we presented in this chapter to wrap up this survey on how IR hedging and cash flow volatility affect firm value and risk for oil producers of our sample.

Conclusion

There are plenty of theoretical studies on the risk management strategies in the literature which explain the effects of hedging activities on firms' value and risk. Additionally, there are plenty of empirical studies which attempt to increase our understanding of the motivations, and the mechanisms of the direct and indirect effects of hedging on firms' performance. More recent empirical works have mainly focused on the effects of traditional hedging instruments (like foreign exchange rate hedging) or total hedging instruments on non-financial firms' value. But, in this study, we go further to examine the effect of cash flow volatility and IR-hedging on oil producers' value and risk through investigating the real marginal effects and average effects (as the mean of marginal effects) of IR-hedging activities. For this purpose, we use the essential heterogeneity model and the parametric method provided by the brand new *MTEFE* command in Stata software for dealing with both sources of selection bias: unobservable variables and gain into treatment.

The estimation process of the aforementioned model consists of two steps. In the first step, we estimate the effects of changes in the Killian index as an instrumental variable for IR-hedging in the presence of the control variables. The results show that the Kilian index is a valid instrument for IR hedging and positively influences IR hedging since a positive change in the Kilian index could result in higher prices of industrial commodities and leads to an increase in oil producers' need for external financing which it could cause more need to do IR hedging. Additionally, cash flow volatility has negative effect on IR-hedging, diversity in gas production has negative effect on IR-hedging, plus firms with more oil reserves and higher leverage ratios that are more exposed to higher risks do more IR-hedging.

The results of the second step show that although the average treatment effect on the firm value is positive for IR-hedgers and negative for non-hedgers, and although the average treatment effect on the market and crash risk is negative for IR-hedgers and positive for non-hedgers, none of the models ATE are significant, implying that there is no evidence to confirm that doing IR-hedging could affect firms' value and risk in terms of average effect.

Cash flow volatility negatively impacts Tobin's q (firm value) and positively influences idiosyncratic and total risk for non-hedgers, where doing IR hedging does not significantly change the effect of cash flow volatility on oil producers' value and risk except when it comes to ROE, where IR-hedging results in the positive effect of cash flow volatility on firm accounting performance.

Moreover, there are some minor results. For example, institutional ownership, CEO option holding, and gas reserves all negatively impact Tobin's q in untreated groups but the effects for hedgers are positive and the difference between their coefficients in the two groups is significant. Institutional ownership has significant negative effect on the systematic risk of non-IR hedgers whereas its different effect on hedgers' systematic risk which is positive is significant too. Oil price volatility increases the systematic risk for non-hedgers but doing IR-hedging changes the effect of oil price volatility; IR-hedgers could be more benefited from volatilities in oil price as the effect of oil price volatility on IR-hedgers' systematic risk is negative.

When it comes to the marginal effect of IR hedging on firms' value and risk, the results show that MTE decreases with unobservable resistance against doing IR-hedging for Tobin's q and increases for systematic risk and crash risk, implying that the oil producers which are more likely to do IR hedging have higher firm value and lower systematic risk and crash risk. However, the estimated MTEs over unobservable resistances are not significant for Tobin's q, systematic risk, and crash risk.

However, estimated MTEs for ROE over unobservable resistance against doing IR hedging is statistically significant on lower quantiles where the resistance on doing IR hedging is lower and firm-quarters are more likely to do IR hedging with higher propensity scores. This result shows the significant positive effect of doing IR hedging on oil producers’ accounting performance. This important result is presented by using MTE analysis where such effect doesn’t appear in standard ATE analysis. This result indicates the necessity of using MTE analysis.

The results of the complementary tests show that there is no evidence supporting the existence of essential heterogeneity in any of the models, which means that gain into treatment will not significantly change due to unobserved factors. Thus, the causal effects of IR-hedging on firms' value and risk are constant for oil producers and do not vary across oil producers due to hidden characteristics. Finally, just MPRTE2 for accounting performance is statistically significant and positive. It indicates that if a policy increases the tendency of oil producers to do IR hedging on the firm-quarters that are on the verge of being treated or a little bit above the critical point, the marginal ROE will significantly increase, implying that a policy that increases oil producers' tendency to do IR hedging have positive effect on firm accounting performance.

Our results confirm the ambiguous effect of IR-hedging activities on firms' value and risk. As stated in the literature review, some empirical works show that firms use interest rate derivative as instruments for speculation which could result in a negative effect on the firm value but some use it as risk management instruments that will turn into higher value. Although the effect of IR hedging on the firm value, systematic risk, and crash risk is convincing to assume that oil producers use interest rate derivatives as risk management instruments, the results are not significant and on the other hand, the effect on idiosyncratic risk and oil beta (which are insignificant too) is positive which confirms the speculating motivation of oil producers in using interest rate derivatives. So, unlike the previous empirical works such as Dionne and Mnasri (2018) according to which the positive effect of hedging on oil producers' value and the negative effect of hedging on their risk are significant, in this essay we do not find significant evidence on the effect of IR-hedging on firms' value and risk as a risk management instrument.

We suggest that in future studies, to divide the usage of interest rate derivatives (as IR hedging instruments) into two groups of voluntary hedging which are used by the decision of managers and mandatory hedging positions that are referred by shareholders and obliged by creditors, and analyze the effect of IR hedging on firm value and risk (Tobin's q, systematic risk, idiosyncratic risk, and crash risk) on two mentioned groups separately because according to previous empirical works, mandatory instruments are more likely to be used as real risk management practices and reward such positions by a premium on firm value. So, the effect of using these two groups of IR-hedging in non-financial firms could have different effects on firm value and risk.

Bibliography

Andresen, Martin E. 2018. “Exploring Marginal Treatment Effects: Flexible Estimation Using Stata.” *The Stata Journal: Promoting Communications on Statistics and Stata* 18(1): 118–58.

Ahmed, H, Azevedo, A & Guney, Y (2013). The effect of hedging on firm value and performance: Evidence from the non-financial UK firms. *1-31*.

Ahmed, H., Fairchild, R. and Guney, Y., 2020. Is corporate hedging always beneficial? A theoretical and empirical analysis. *European Journal of Finance*, 26(17), 1746-1780.

Allayannis, G. and Weston, J.P., 2001. The use of foreign currency derivatives and firm market value. *Review of Financial Studies* 14, 243–276.

Altuntas, M., Liebenberg, A.P., Watson E.D, and Yildiz S.,2017. Hedging, Cash Flows, and Firm Value: Evidence of an Indirect Effect. *Journal of Insurance Issues* 40, No. 1, 1-22.

Angrist, D. Joshua, Krueger, Alan B., 2001. Instrumental variables and the search for identification: From supply and demand to natural experiments. *Journal of Economic Perspectives.* 15 (4), 69–85.

Aretz, K. and Bartram, S.M., 2010. Corporate hedging and shareholder value. *Journal of Financial Research* 33, 317–371.

Bartram, S.M., Brown, G.W., and Conrad, J., 2011. The effects of derivatives on firm risk and value. *Journal of Financial and Quantitative Analysis* 46, 967–999.

Brave, S. and Walstrum, T., 2014. Estimating marginal treatment effects using parametric and semiparametric methods. *Stata Journal* 14, 191–217.

Carneiro, P., Heckman, J.J., and Vytlacil, E.J., 2009. Evaluating marginal policies and the average treatment for individuals at the margin. NBER working paper 15211.

Carneiro, P., Heckman, J.J., and Vytlacil, E.J., 2010. Estimating marginal returns to education. NBER working paper 16474.

Cornelissen, T., Dustmann, C., Raute, A. und Schonberg, U. (2016). From LATE to MTE: Alternative methods for the evaluation of policy interventions. *Labour Economics*, 41, 47-60.

Covitz, D., Sharpe, S.A., 2005. Do Nonfinancial Firms Use Interest Rate Derivatives to Hedge? *Finance and Economics Discussion Series Working Paper* No.2005-39. The Federal Reserve Board, Washington, D.C.

Dan, C. Gu, H.& Xu, K. (2005). The Impact of Hedging on Stock Return and Firm Value. *Department of Economics Department of Mathematics and Statistics Dalhousie University.*

Dionne, G., and Triki, T., 2013. On risk management determinants: What really matters? *European Journal of Finance* 19, 145-164.

Dionne, G., Gueyie, J.P., and Mnasri, M., 2018. Dynamic corporate risk management: Motivations and real implications. *Journal of Banking and Finance* 95, 97-111.

Dionne, G., and Mnasri, M., 2018. Real implications of corporate risk management: Review of main results and new evidence from a different methodology. *L'actualité Economique* 94, 407-452.

Fauver, L. and Naranjo, A., 2010. Derivative usage and firm value: The influence of agency costs and monitoring problems. *Journal of Corporate Finance* 16, 719–735.

Froot, K.A., Scharfstein, D. and Stein, J., 1993. Risk Management: Coordinating Corporate Investment and Financing Policies. *Journal of Finance* 48, 1629–1658.

Gilje, E.P. and Taillard, J.P. (2017), "Does hedging affect firm value? Evidence from a natural experiment", *Review of Financial Studies*, Vol. 30 No. 12, pp. 4083-4132.

Graham J.R. and Smith, C.W., 1999. Tax incentives to hedge. Journal of Finance 54, 2241-2262.

Graham, J.R. and Rogers, D.A., 2002. Do firms hedge in response to tax incentives? *Journal of Finance* 57, 815-839.

Hang, M., Geyer-Klingeberg, J., Rathgeber, A., Stockl, S., 2020. Rather Complements than Substitutes: Firm Value Effects of Capital Structure and Financial Hedging Decisions. *International Journal of Finance and Economics Forthcoming*. doi: 10.1002/ijfe.2045.

Heckman, J.J., Urzua, S., and Vytlacil, E.J., 2006. Understanding instrumental variables in models with essential heterogeneity. *Review of Economics and Statistics* 88, 389–432.

Hentschel, L. and Kothari, S.P., 2001. Are corporations reducing or taking risks with derivatives? *Journal of Financial and Quantitative Analysis* 36, 93-118.

Jin, Y. and Jorion, P., 2006. Firm value and hedging: Evidence from U.S. oil and gas producers. *Journal of Finance* 61, 893-919.

Kilian, L., 2009. Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review* 99, 1053–1069.

Geyer-Klingeberg, J., Hang, M., & Rathgeber, A. (2020). Corporate Financial hedging and firm value: A meta-analysis. *SSRN Working Paper*.

KPMG (2013). Expectations of risk management outpacing capabilities – It’s time for action, Publication number: 121405a.

Kumar, P. and Rabinovitch, R., 2013. CEO entrenchment and corporate hedging: Evidence from the oil and gas industry. *Journal of Financial and Quantitative Analysis* 48, 887-917.

Marami, A., and Dubois, M. (2013). Interest rate derivatives and firm value: evidence from mandatory versus voluntary hedging. *SSRN Working Paper*.

Mincer J., 1974. Schooling, Experience and Earnings. New York: National Bureau of Economic Research.

Mnasri, M., Dionne, G., and Gueyie, J.P., 2017. The use of nonlinear hedging strategies by US oil producers: Motivations and implications. *Energy Economics* 63, 348-364.

Mohammed, H. K., & Knápková, A. (2016). The impact of total risk management on company's performance. *Procedia-Social Behavioral Science*, 220, 271–277.

Morck, R., Shleifer, A. and Vishny, R.W. (1988). Management ownership and market valuation: An empirical analysis. *Journal of Financial Economics*, *20*(1–2), 293–315.

Morellec, E., Smith, C.W., 2007. Agency conflicts and risk management. *Review of Finance* 11, 1-23.

Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics 13*(2), 187- 221.

Pérez-Gonzalez, F. and Yun, H., 2013. Risk management and firm value: Evidence from weather derivatives. *Journal of Finance* 68, 2143-2176.

Ravazzolo, F., and Vespignani, J. L. (2016) 'A new monthly indicator of global real economic activity'. Available at: https://www.ecb.europa.eu/pub/conferences/shared/pdf/20160603_forecasting/Paper_for_poster_5_Ravazzolo.pdf

Seok, S.-I., Kim, T.-H., Cho, H. and Kim, T.-J. (2020), "Determinants of hedging and their impact on firm value and risk: after controlling for endogeneity using a two-stage analysis", *Journal of Korea Trade*, Vol. 24 No. 1, pp. 1-34.

Smith, C.W. and Stulz, R.M., 1985. The determinants of firms' hedging policies. *Journal of Financial and Quantitative Analysis* 20, 4, 391-405.

Stulz, R.M., 1996. Rethinking risk management. *Journal of Applied Corporate Finance* 9, 8-24.

Tufano, P., 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. *Journal of Finance* 51, 1097-1137.

Tufano, P., 1998. The determinants of stock price exposure: Financial engineering and the gold mining industry. *Journal of Finance* 53, 1015-1052.

Tufano, P., 2003, 'Financial innovation', *Handbook of the Economics of Finance* 1, 307–355.

Zamzamin, Z.Z., Haron, R. and Abdullah Othman, A.H. (2021), "Hedging,managerial ownership and firm value", *Journal of Asian Business and Economic Studies,* Vol. ahead-of-print No. ahead-of-print.,avaialble at: https://doi.org/10.1108/JABES-08-2020-0101.

Appendix A

Essential Heterogeneity model

Here we go more deeply through the way which we arrived to essential heterogeneity model which has been introduced concisely in chapter 3, methodology:

We will use Heckman et al (2005, 2006, 2010)'s way named *essential heterogeneity method* which controls for the individual-specific unobserved heterogeneity in the estimation of marginal treatment effects (MTEs) of doing IR hedging versus non-hedgers. In the following, we will introduce the model based on generalized Roy model in a mathematical approach.

In Roy model we face an equilibrium model for work selection. The generalized Roy Model is a basic choice-theoretic framework for decision analysis. According to difference between IR hedged firms and non-hedged ones, one can assume two estimations (equations A.1 and A.2) on output as following:

$$Y_{0i} = \alpha_0 + X_{ij}\beta_{0j} + U_{0i} \quad \text{(A.1)}$$

$$Y_{1i} = \alpha_1 + \beta_1 + X_{ij}\beta_{1j} + U_{1i} \quad \text{(A.2)}$$

$$Y_D = DY_{1i} + (1 - D)Y_{0i} \quad \text{(A.3)}$$

$$I_i = \theta Z_i - V_i \quad \text{(A.4)}$$

$$D = \begin{cases} 0, & I_i < 0 \\ 1, & I_i \geq 0 \end{cases} \quad \text{(A.5)}$$

Conditional on counterfactual treatment decisions, Y_{1i} is the potential output of firm performance (firm value or risk) if the firm does IR hedging (treated firm), Y_{0i} is potential firm performance (firm value or risk) if the firm doesn't IR hedging (not treated). Firm performances are linearly dependent on X_{ij} (observed control variables) and unobserved components of U_{0i} and U_{1i} as error terms and β_1 $(in\ eq. 3.1)$ is the benefit of being treated (doing IR hedging).

The decision process for the treatment (whether do IR hedging or don't) indicator is I_i which is posed as a function of observables Z_i (control variables plus instrumental variable (delta Kilian index)) and unobservables V_i. So, according to A.3, A.4, and A.5 equations, the decision process for treatment is linked to the observed firm performance (Y_D) through the latent variable (I_i). If the answer of equation A.4 after estimation of coefficient θ by using a bunch of control variables plus instrumental variable become less or equal to zero then D goes to 0 and $Y_D = Y_{0i}$ shows an untreated firm-quarter. If I_i becomes bigger than zero, D becomes 1 and shows a treated firm-quarter and $Y_D = Y_{1i}$.

In the following, we will drop the subscripts which indicate firms (i), time (t), and even a set of control variables (j) to make the equations simpler. We have to remind that when we talk about X this could show a set of control variables matrix, Z (one or) a set of instruments (which we decide to use just one instrument in our model =Kilian index), etc.

Model is involved with parametric restrictions on U_{0i}, U_{1i}, V_i (U_0, U_1, V), and Z_i (Z) which put constraints to satisfy:

$$Cov(Z, U_1) = 0\ ,\ \ Cov(Z, U_0) = 0\ ,\ \ and\ \theta \neq 0 \qquad \text{(A.6)}$$

$$(U_0, U_1, V) \sim N(0, \Sigma) \qquad \text{(A.7)}$$

$$Where:\ \ Cov(V, U_1) = \sigma_{v1}\ ,\ Cov(V, U_0) = \sigma_{v0}\ , \sigma_v^2 = 1 \qquad \text{(A.8)}$$

We can rearrange the potential outcomes (firm performances) equations A.1– A.5 to show the probability of participation in treatment to go to MTE calculations:

$$Y_0 = \mu_0(X) + U_0 \qquad \text{(A.9)}$$

$$Y_1 = \mu_1(X) + U_1 \qquad \text{(A.10)}$$

Where $\mu_0(X)$ and $\mu_1(X)$ are the mean or more precisely conditional expectation of firm performance (outcomes) respectively when there is hedging or not conditional on control variables and instrumental variables matrix provided. In other words:

$$Where: \mu_0(X) = E(Y_0|X = x) \quad and \quad \mu_1(X) = E(Y_1|X = x) \qquad \text{(A.11)}$$

Now we can say that β_1 (in equation 3.1) is the effect of IR Hedging on firm performance, or in another word, the return to IR hedging could be given by this equation:

$$\beta_1 = Y_1 - Y_0 = \mu_1(X) - \mu_0(X) + U_1 - U_0 \qquad \text{(A.12)}$$

It may happen that by controlling for the X, we may be lucky to have the same $Y_1 - Y_0$ for all firms we are studying in our sample. This is the case of homogenous treatment effects given X. In that sense, we just need to estimate the IV model with 2SLS, but according to previous empirical studies it is more likely that firms vary in their response to the IR hedging even after controlling for plenty of relevant variables in matrix X. As we will show in the following, the different effects (β_1) causes by $U_1 - U_0$ term which contains the effect of unobserved variables that affect the effect of IR hedging (the coefficient β_1) and firm performance since the term $\mu_1(X) - \mu_0(X)$ is constant for all firms and is equal to treatment effect under homogeneous effects assumption.

According to equation A.12 and in coincidence with what was mentioned in the previous paragraph, the average treatment effect conditional on $X = x$ is given by

$$\overline{\beta_1}(x) = E(\beta_1|X = x) = \mu_1(X) - \mu_0(X) \qquad \text{(A.13)}$$

So, if we consider the heterogeneity on treatment effect which assumes that the mean of the second term is not essentially equal to zero: $E(U_1 - U_0|X = x) \neq 0,$ the average effect of treatment on those who have done IR hedging conditional on $X = x$ is given by

$$E(\beta_1|X = x, D = 1) = \overline{\beta_1}(x) + E(U_1 - U_0|X = x, D = 1) \qquad \text{(A.14)}$$

The control variables (X) need not be statistically independent of unobserved ones (U_1, U_0). Now we can go back to the equations A.1 to A.6 and through this parametric approach, the discrete choice model (equation A.4) for firms to do IR hedging is just a conventional probit ($V \sim N(0,1) \rightarrow {\sigma_v}^2 = 1$) and the propensity score is given by:

$$P(z) = Pr(D = 1|Z = z) = \Pr(I > 0) = \Pr(\theta Z > V) = F_v(\theta Z) = \Phi(\theta Z) \quad \text{(A.15)}$$

Where $P(z)$ denotes the probability of doing IR hedging conditional on Z=z. If we define $U_D = F_v(V)$, U_D as a cumulative distribution of standard normal variable V will be uniformly distributed, and different values of V will give out different values of U_D. So, by using A.15, we have:

$$P(Z) = F_v(\theta Z)\,,\ D = 1\ (treatment\ is\ done)\ if\ P(Z) \geq U_D \qquad \text{(A.16)}$$

$$or\ equivalantly:\ \Phi(\theta Z) \geq \Phi(V)$$

Using equation A.16, we can interpret $P(Z)$ (propensity score) as the probability of being treated or doing IR hedging and U_D as the resistance against being treated in each firm from unobserved variables. So, the bigger $P(Z)$ means more probability to oil producers to do IR hedging and a bigger U_D will entice oil producers more to do not go for IR hedging decisions. And when $P(Z) = U_D$ is the indifference level for an oil producer to resist against doing IR hedging or do that. Hence, by using equations A.12 and A.14 the marginal treatment effects (MTEs) will be defined:

$$MTE(x, u_D) = E(\beta_1|X = x, U_D = u_D) = E(Y_1 - Y_0|X = x, U_D = u_D) \qquad \text{(A.17)}$$

Moreover, as we defined on equation A.14:

$$ATE = E(\beta_1|X = x) = E(Y_1 - Y_0|X = x) \qquad \text{(A.18)}$$

MTE is the mean return (firm performance outcome) to doing IR hedging for the firm that $X = x, and\ U_D = u_D$. We can go more in simplification by using A.1 and A.2 to get:

$$MTE = E(Y_1 - Y_0|X = x, U_D = u_D) = (\alpha_1 + \beta_1 - \alpha_0) + X_{ij}(\beta_{1j} - \beta_{0j}) + E(U_1 - U_0|X = x, U_D = u_D) \qquad \text{(A.19)}$$

In equation A.19 only, the last term is not completely defined, we will return to this for more simplification later.

As we defined before, U_D has been normalized as a unit uniform distribution, so if we trace MTE over U_D values, we can define how the returns to IR hedging vary with different quantiles of the unobserved component of the resistance to do IR hedging.

For estimating MTE, we will use the local instrumental variables method used by Heckman and Vytlacil (2006) which is identified by differentiating $E(Y|X = x, P(Z) = p)$ with respect to p, which can be computed over the support of the distribution of P(Z). Therefore, we return to Y and by some manipulation on equations A.3, A.9, A.10, and A.12 we can show:

$$Y = DY_1 + (1 - D)Y_0 = D(\mu_1(X) + U_1) + (1 - D)(\mu_0(X) + U_0) =$$

$$\mu_0(X) + [\mu_1(X) - \mu_0(X) + U_1 - U_0]D + U_0 =$$

$$\mu_0(X) + [\mu_1(X) - \mu_0(X)]D + (U_0 + (U_1 - U_0)D) \qquad \text{(A.20)}$$

Then

$$E(Y|X = x, P(Z) = p) = E(Y_0|X = x, P(Z) = p) + E(Y_1 - Y_0|X = x, P(Z) = p) \times p \qquad \text{(A.21)}$$

By using equations A.22 and A.5:

$$E(Y|X = x, P(Z) = p) \qquad \text{(A.22)}$$
$$= \mu_0(X) + [\mu_1(X) - \mu_0(X)]p$$
$$+ \int_{-\infty}^{+\infty} \int_0^p (u_1 - u_0) f(u_1 - u_0|X = x, U_D = u_D) du_D d(u_1 - u_0)$$

Under the assumption of $(U_1 - U_0)$ being a continuous random variable, $f(u_1 - u_0|X = x, U_D = u_D)$ is the conditional density distribution function of $U_1 - U_0$.

Now by using the MTE definition on equations A.17 and A.19, we can rewrite that two last terms of equation A.21 as an integral of MTE:

$$E(Y|X=x, P(Z)=p) = \mu_0(X) + \int_0^p MTE(x, u_D)du_D \quad \text{(A.23)}$$

By using derivatives basic rules and as the right-hand side of the equation A.23 could easily and consistently be estimated from the sample data we can find:

$$MTE(x, p) = \partial E(Y|X=x, P(Z)=p)/\partial p \quad \text{(A.24)}$$

This is the local instrumental variable (LIV) estimator and we can recover the return to IR hedging for firms indifferent between D = 1 and D = 0 at all margins of U_D within the empirical support of P(Z) (conditional on X). Therefore, firms with a high mean scale utility function P(Z) identify the return for those with a high value of U_D, as now we know that the value of U_D makes firms less likely to participate in IR hedging.

Marginal increases in P(Z) starting from high values of P(Z) induce those firms with high U_D values into doing IR hedging activities. Those with low values of U_D are already treated for such values of P(Z) so that a marginal increase in P(Z) starting from a high value doesn't affect those with low values of U_D. As, the quantity of P(Z) and U_D can determine firms treatment selection, hence, firms identified by the quantile of the unobserved component of the desire to do IR hedging could be recognized that really are induced to do IR hedging (D = 1) by a marginal change in P(Z).

According to Carneiro, Heckman and Vytlacil (2010) and equations A.17 and A.18, we can define standard measures of the return (outcome, firm performances) to IR hedging such as the average return to IR hedging in the whole sample: ($ATE = E(\beta_1|X=x)$) and the average return to IR hedging among those who have done IR hedging ($E(\beta_1|X=x, D=1)$, can be expressed as different weighted averages of the MTE. So, we can show that treatment parameter IR, $\Delta_{IR}(x)$ can be written as a weighted average of the MTE:

$$\Delta_{IR}(x) = \int_0^1 MTE(x, u_D)h_{IR}(x, u_D)du_D \quad \text{(A.25)}$$

Equations A.24 and A.25 give the best mathematical and economical definition on marginal treatment effect and average weighted on marginal treatment effect in the case of having more than one instrument in our model. We predict we will just use one instrument to increase our model to have a more precise and efficient estimation. Since in essential heterogeneity models according to Heckman's work, MTE takes a main central role in the model, we will return to equation A.19 to give a more prrecise statistical description on marginal treatment effect as our last parts of methodology description.

In equation A.19, just the last term was non-specified so for giving a more precise definition on MTE we have to work on $E(U_1 - U_0|X = x,\ U_D = u_D)$.

Since we will work on essential heterogeneity model through the parametric method for estimating our model's parameters according to Brave and Walstrum (2014) and Dionne and Mnasri (2018) we have:

$$E(U_1|X = x, U_D = u_D) = E(U_1|X = x, P(Z) = p, D = 1) = \sigma_{v1}\left(-\frac{\phi(p)}{p*\Phi(p)}\right) \quad \text{(A.26)}$$

$$E(U_0|X = x, U_D = u_D) = E(U_0|X = x, P(Z) = p, D = 0) = \sigma_{v0}\left(\frac{\phi(p)}{(1-p)*\Phi(p)}\right) \quad \text{(A.27)}$$

We can use equations A.26 and A.27 for calculation of Y_0 and Y_1 and use equation A.19 for final the calculations on MTE.

As we assumed under equations A.7, error terms of U_0, U_1, and V are normally joint distributed, so the covariances σ_{v0} and σ_{v1} are the inverse Mills ratios coefficients, and right-hand-side expression in A.26 and A.27 are inverse Mills ratio for treated and untreated samples which we will see as $\sigma_{v1} - \sigma_{v0}$ (which in STaTa it is named as ($\rho_1 - \rho_0$)). They are estimated separately along with the other parameters in A.28 and A.29 equations. Note that to make it easier to follow the formula we dropped i,j subscripts, indicate each variable and firm-quarter.

$$E(Y_1|X = x, P(Z) = p, D = 1) = \alpha_1 + \beta_1 + X_{ij}\beta_{1j} + E(U_1|X = x, U_D = u_D) =$$

$$= \alpha_1 + \beta_1 + X\beta_{1j} + \sigma_{v1}\left(-\frac{\phi(p)}{p*\Phi(p)}\right) \quad \text{(A.28)}$$

$$E(Y_0|X = x, P(Z) = p, D = 0) = \alpha_0 + X_{ij}\beta_{0j} + E(U_0|X = x, U_D = u_D) =$$

$$= \alpha_0 + X\beta_{0j} + \sigma_{v0}\left(\frac{\phi(p)}{(1-p)*\Phi(p)}\right) \qquad \text{(A.29)}$$

So, by some manipulation on A.28 and A.29, we have:

$$MTE(X = x, U_D = u_D) = E(Y_1 - Y_0|X = x, U_D = u_D) = \qquad \text{(A.30)}$$

$$(\alpha_1 + \beta_1 - \alpha_0) + X_{ij}(\beta_{1j} - \beta_{0j}) + E(U_1 - U_0|X = x, U_D = u_D) =$$

$$(\alpha_1 + \beta_1 - \alpha_0) + X(\beta_{1j} - \beta_{0j}) + (\sigma_{v1} - \sigma_{v0})\Phi^{-1}(u_D)$$

Finally, for estimating marginal treatment effect we can use the estimated propensity score (P(Z)):

$$MT\widehat{E(x, u_D)} = \widehat{\alpha_1 + \beta_1} - \widehat{\alpha_0} + X(\widehat{\beta_{1j}} - \widehat{\beta_{0j}}) + (\widehat{\sigma_{v1}} - \widehat{\sigma_{v0}})\Phi^{-1}(u_D) \qquad \text{(A.31)}$$

According to definition, the way that MTE changes over the range of unobserved resistance on doing IR hedging which is given by the cumulative distribution of error terms in regression of instrumental variable and control variables on IR hedging decision ($U_D = \Phi(V)$), is a sign of the existence of the heterogeneous treatment effects in our oil producers' sample. This change is the way which β_1 (the coefficient of doing IR hedging) in the firm performance estimation model is correlated by U_D as "treatment indicator".

Identically, the estimated changing MTE shows how a rise in the marginal outcome (firm value, risk) by going from choice non-IR-hedgers to doing IR hedging varies with different quantiles of the unobserved component V in the choice equation. As $U_D$shows the latent unobserved resistance of doing IR hedging, when MTE increases (decreases) with U_D means that the coefficient β_1 is negatively (positively) correlated with the latent tendency of using IR hedging for oil production.

For wrapping up, we will present the complementary expression on propensity score and MTE in the parametric method of essential heterogeneity model estimation by relaxing the assumption of joint normality, which also allows propensity score ($P(\mathbf{Z})$) to be fit by another probability model like a linear probability or logit model. The linear probability model should be used with caution as the range for $P(\mathbf{Z})$ is not constrained to be between 0 and 1.

By using A.21, we can show that

$$E(Y|X = x, P(Z) = p) = \alpha_0 + X\beta_0 + (\alpha_1 - \alpha_0)p + X(\beta_{1j} - \beta_{0j})p + \sum_{k=1}^{g} \phi_k \, p^k \qquad \text{(A.32)}$$

Where conditional expectations on $U_0$and U_1 in equation A.21 are approximated by a polynomial in p of chosen degree g. Now by using equation A.32 and using the way we used in equation A.24, we can define the MTE as the partial derivative of the conditional expectation of Y with respect to $P(\mathbf{Z})$,

$$MTE(x, p) = \partial E(Y|X = x, P(Z) = p)/\partial p = \qquad \text{(A.33)}$$

$$= (\alpha_1 - \alpha_0) + X(\beta_{1j} - \beta_{0j}) + \sum_{k=1}^{g} k\phi_k \, p^{k-1}$$

If we use linear regression or logit model instead of the probit, the parameters will be estimated by the linear regression like A.33, and the coefficient on $P(\mathbf{Z})$ (first degree of the propensity score in polynomial condition) ϕ_1, in this regression includes $\alpha_1 - \alpha_0$ so that all the parameters of the MTE are identified.

Appendix B

Estimated MTEs tables

Table: B.1: Estimated MTEs for Tobin's q

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	4.652	u23	-4.707	u45	-8.322	u67	-11.66	u89	-16.29
	(4.016)		(4.750)		(7.849)		(10.76)		(14.82)
u2	3.045	u24	-4.899	u46	-8.471	u68	-11.82	u90	-16.62
	(2.743)		(4.912)		(7.978)		(10.90)		(15.11)
u3	2.025	u25	-5.087	u47	-8.620	u69	-11.99	u91	-16.97
	(2.037)		(5.070)		(8.107)		(11.04)		(15.41)
u4	1.258	u26	-5.270	u48	-8.768	u70	-12.16	u92	-17.35
	(1.638)		(5.226)		(8.236)		(11.19)		(15.75)
u5	0.634	u27	-5.450	u49	-8.916	u71	-12.33	u93	-17.76
	(1.471)		(5.378)		(8.364)		(11.34)		(16.11)
u6	0.103	u28	-5.627	u50	-9.063	u72	-12.50	u94	-18.23
	(1.484)		(5.529)		(8.493)		(11.49)		(16.52)
u7	-0.362	u29	-5.801	u51	-9.211	u73	-12.68	u95	-18.76
	(1.611)		(5.677)		(8.621)		(11.65)		(16.99)
u8	-0.779	u30	-5.972	u52	-9.359	u74	-12.86	u96	-19.39
	(1.799)		(5.823)		(8.750)		(11.81)		(17.54)
u9	-1.159	u31	-6.140	u53	-9.507	u75	-13.04	u97	-20.15
	(2.013)		(5.967)		(8.879)		(11.97)		(18.21)
u10	-1.508	u32	-6.306	u54	-9.655	u76	-13.23	u98	-21.17
	(2.237)		(6.109)		(9.008)		(12.13)		(19.11)
u11	-1.832	u33	-6.470	u55	-9.804	u77	-13.42	u99	-22.78
	(2.461)		(6.249)		(9.138)		(12.30)		(20.53)
u12	-2.136	u34	-6.632	u56	-9.953	u78	-13.62		
	(2.682)		(6.388)		(9.268)		(12.47)		
u13	-2.422	u35	-6.792	u57	-10.10	u79	-13.82		
	(2.897)		(6.526)		(9.398)		(12.65)		
u14	-2.694	u36	-6.950	u58	-10.25	u80	-14.03		
	(3.107)		(6.662)		(9.530)		(12.83)		
u15	-2.953	u37	-7.107	u59	-10.40	u81	-14.24		
	(3.310)		(6.798)		(9.662)		(13.02)		
u16	-3.200	u38	-7.262	u60	-10.56	u82	-14.46		
	(3.508)		(6.932)		(9.794)		(13.21)		
u17	-3.438	u39	-7.417	u61	-10.71	u83	-14.69		
	(3.700)		(7.065)		(9.928)		(13.41)		
u18	-3.667	u40	-7.570	u62	-10.86	u84	-14.93		
	(3.886)		(7.197)		(10.06)		(13.62)		
u19	-3.887	u41	-7.722	u63	-11.02	u85	-15.17		
	(4.068)		(7.329)		(10.20)		(13.84)		
u20	-4.101	u42	-7.873	u64	-11.18	u86	-15.43		
	(4.244)		(7.460)		(10.34)		(14.07)		
u21	-4.309	u43	-8.023	u65	-11.34	u87	-15.70		
	(4.417)		(7.590)		(10.47)		(14.30)		
u22	-4.511	u44	-8.173	u66	-11.50	u88	-15.99		
	(-4.585)		(7.720)		(10.61)		(14.56)		

Table: B.2: Estimated MTEs for ROE

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	-1.504	u26	4.107	u51	6.336	u76	8.607
	(1.716)		(2.556)		(4.181)		(5.850)
u2	-0.595	u27	4.209	u52	6.419	u77	8.715
	(1.093)		(2.630)		(4.243)		(5.929)
u3	-0.0183	u28	4.309	u53	6.503	u78	8.826
	(0.743)		(2.702)		(4.304)		(6.011)
u4	0.415	u29	4.407	u54	6.587	u79	8.940
	(0.555)		(2.773)		(4.366)		(6.095)
u5	0.768	u30	4.504	u55	6.671	u80	9.058
	(0.510)		(2.843)		(4.427)		(6.182)
u6	1.069*	u31	4.599	u56	6.755	u81	9.179
	(0.572)		(2.913)		(4.489)		(6.271)
u7	1.332*	u32	4.693	u57	6.840	u82	9.304
	(0.683)		(2.981)		(4.551)		(6.362)
u8	1.568*	u33	4.785	u58	6.925	u83	9.433
	(0.809)		(3.048)		(4.614)		(6.458)
u9	1.782*	u34	4.877	u59	7.011	u84	9.567
	(0.938)		(3.115)		(4.677)		(6.557)
u10	1.979*	u35	4.967	u60	7.097	u85	9.707
	(1.063)		(3.181)		(4.740)		(6.660)
u11	2.163*	u36	5.057	u61	7.183	u86	9.854
	(1.184)		(3.246)		(4.803)		(6.767)
u12	2.335*	u37	5.146	u62	7.270	u87	10.01
	(1.300)		(3.311)		(4.867)		(6.880)
u13	2.497*	u38	5.234	u63	7.358	u88	10.17
	(1.411)		(3.375)		(4.932)		(7.000)
u14	2.650*	u39	5.321	u64	7.447	u89	10.34
	(1.517)		(3.439)		(4.997)		(7.126)
u15	2.797*	u40	5.407	u65	7.537	u90	10.52
	(1.619)		(3.502)		(5.063)		(7.261)
u16	2.937*	u41	5.493	u66	7.627	u91	10.72
	(1.717)		(3.565)		(5.129)		(7.407)
u17	3.071*	u42	5.579	u67	7.719	u92	10.94
	(1.812)		(3.627)		(5.197)		(7.565)
u18	3.200*	u43	5.664	u68	7.811	u93	11.17
	(1.904)		(3.690)		(5.265)		(7.739)
u19	3.325*	u44	5.749	u69	7.905	u94	11.44
	(1.993)		(3.752)		(5.334)		(7.933)
u20	3.446*	u45	5.833	u70	8.000	u95	11.74
	(2.080)		(3.813)		(5.404)		(8.154)
u21	3.563*	u46	5.917	u71	8.097	u96	12.09
	(2.164)		(3.875)		(5.475)		(8.414)
u22	3.678	u47	6.001	u72	8.195	u97	12.52
	(2.246)		(3.936)		(5.547)		(8.734)
u23	3.789	u48	6.085	u73	8.295	u98	13.10
	(2.326)		(3.998)		(5.620)		(9.159)
u24	3.897	u49	6.168	u74	8.397	u99	14.01
	(2.404)		(4.059)		(5.695)		(9.829)
u25	4.003	u50	6.252	u75	8.501		
	(2.481)		(4.120)		(5.772)		

Table: B.3: Estimated MTEs for idiosyncratic risk

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	0.100	u26	-0.0141	u51	-0.0594	u76	-0.106
	(0.102)		(0.145)		(0.238)		(0.334)
u2	0.0815	u27	-0.0161	u52	-0.0611	u77	-0.108
	(0.0663)		(0.149)		(0.242)		(0.339)
u3	0.0698	u28	-0.0182	u53	-0.0628	u78	-0.110
	(0.0462)		(0.153)		(0.245)		(0.344)
u4	0.0610*	u29	-0.0202	u54	-0.0645	u79	-0.112
	(0.0350)		(0.157)		(0.249)		(0.348)
u5	0.0538*	u30	-0.0221	u55	-0.0662	u80	-0.115
	(0.0315)		(0.161)		(0.252)		(0.353)
u6	0.0477	u31	-0.0241	u56	-0.0679	u81	-0.117
	(0.0338)		(0.165)		(0.256)		(0.359)
u7	0.0424	u32	-0.0260	u57	-0.0696	u82	-0.120
	(0.0393)		(0.169)		(0.260)		(0.364)
u8	0.0376	u33	-0.0278	u58	-0.0713	u83	-0.122
	(0.0460)		(0.173)		(0.263)		(0.369)
u9	0.0332	u34	-0.0297	u59	-0.0731	u84	-0.125
	(0.0531)		(0.177)		(0.267)		(0.375)
u10	0.0292	u35	-0.0315	u60	-0.0748	u85	-0.128
	(0.0600)		(0.181)		(0.270)		(0.381)
u11	0.0255	u36	-0.0334	u61	-0.0766	u86	-0.131
	(0.0668)		(0.185)		(0.274)		(0.387)
u12	0.0220	u37	-0.0352	u62	-0.0784	u87	-0.134
	(0.0733)		(0.188)		(0.278)		(0.394)
u13	0.0187	u38	-0.0370	u63	-0.0801	u88	-0.137
	(0.0796)		(0.192)		(0.282)		(0.400)
u14	0.0156	u39	-0.0387	u64	-0.0819	u89	-0.141
	(0.0856)		(0.196)		(0.285)		(0.408)
u15	0.0126	u40	-0.0405	u65	-0.0838	u90	-0.145
	(0.0914)		(0.199)		(0.289)		(0.416)
u16	0.00974	u41	-0.0422	u66	-0.0856	u91	-0.149
	(0.0970)		(0.203)		(0.293)		(0.424)
u17	0.00701	u42	-0.0440	u67	-0.0875	u92	-0.153
	(0.102)		(0.207)		(0.297)		(0.433)
u18	0.00438	u43	-0.0457	u68	-0.0894	u93	-0.158
	(0.108)		(0.210)		(0.301)		(0.443)
u19	0.00184	u44	-0.0474	u69	-0.0913	u94	-0.163
	(0.113)		(0.214)		(0.305)		(0.454)
u20	-0.000620	u45	-0.0491	u70	-0.0932	u95	-0.169
	(0.118)		(0.217)		(0.309)		(0.467)
u21	-0.00301	u46	-0.0509	u71	-0.0952	u96	-0.176
	(0.123)		(0.221)		(0.313)		(0.482)
u22	-0.00532	u47	-0.0526	u72	-0.0972	u97	-0.185
	(0.127)		(0.224)		(0.317)		(0.500)
u23	-0.00758	u48	-0.0543	u73	-0.0992	u98	-0.197
	(0.132)		(0.228)		(0.321)		(0.525)
u24	-0.00979	u49	-0.0560	u74	-0.101	u99	-0.215
	(0.136)		(0.231)		(0.325)		(0.563)
u25	-0.0119	u50	-0.0577	u75	-0.103		
	(0.141)		(0.235)		(0.330)		

Table: B.4: Estimated MTEs for systematic risk

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	-2.847	u26	2.852	u51	5.115	u76	7.422
	(3.334)		(4.263)		(6.990)		(9.821)
u2	-1.924	u27	2.955	u52	5.200	u77	7.532
	(2.332)		(4.385)		(7.094)		(9.957)
u3	-1.338	u28	3.057	u53	5.285	u78	7.645
	(1.789)		(4.505)		(7.198)		(10.10)
u4	-0.898	u29	3.156	u54	5.370	u79	7.761
	(1.490)		(4.623)		(7.302)		(10.24)
u5	-0.539	u30	3.255	u55	5.456	u80	7.880
	(1.365)		(4.740)		(7.406)		(10.39)
u6	-0.234	u31	3.351	u56	5.541	u81	8.003
	(1.368)		(4.856)		(7.511)		(10.54)
u7	0.0332	u32	3.447	u57	5.627	u82	8.130
	(1.455)		(4.970)		(7.616)		(10.69)
u8	0.273	u33	3.541	u58	5.714	u83	8.261
	(1.589)		(5.082)		(7.722)		(10.86)
u9	0.490	u34	3.634	u59	5.801	u84	8.397
	(1.747)		(5.194)		(7.828)		(11.02)
u10	0.691	u35	3.725	u60	5.888	u85	8.540
	(1.914)		(5.304)		(7.936)		(11.20)
u11	0.877	u36	3.816	u61	5.976	u86	8.688
	(2.084)		(5.414)		(8.043)		(11.38)
u12	1.052	u37	3.907	u62	6.065	u87	8.844
	(2.254)		(5.523)		(8.152)		(11.58)
u13	1.216	u38	3.996	u63	6.154	u88	9.009
	(2.421)		(5.630)		(8.262)		(11.78)
u14	1.372	u39	4.084	u64	6.244	u89	9.183
	(2.584)		(5.737)		(8.372)		(12.00)
u15	1.521	u40	4.172	u65	6.335	u90	9.370
	(2.743)		(5.844)		(8.484)		(12.23)
u16	1.663	u41	4.260	u66	6.427	u91	9.570
	(2.898)		(5.950)		(8.597)		(12.47)
u17	1.799	u42	4.347	u67	6.520	u92	9.788
	(3.049)		(6.055)		(8.711)		(12.74)
u18	1.931	u43	4.433	u68	6.614	u93	10.03
	(3.197)		(6.160)		(8.827)		(13.04)
u19	2.058	u44	4.519	u69	6.709	u94	10.29
	(3.340)		(6.264)		(8.944)		(13.37)
u20	2.180	u45	4.605	u70	6.806	u95	10.60
	(3.481)		(6.368)		(9.063)		(13.75)
u21	2.300	u46	4.690	u71	6.904	u96	10.96
	(3.618)		(6.472)		(9.183)		(14.19)
u22	2.416	u47	4.775	u72	7.004	u97	11.40
	(3.752)		(6.576)		(9.306)		(14.74)
u23	2.528	u48	4.860	u73	7.105	u98	11.98
	(3.883)		(6.679)		(9.431)		(15.46)
u24	2.639	u49	4.945	u74	7.209	u99	12.91
	(4.012)		(6.783)		(9.558)		(16.61)
u25	2.746	u50	5.030	u75	7.314		
	(4.138)		(6.886)		(9.688)		

Table: B.5: Estimated MTEs for total risk (Sigma)

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	2.205	u26	-1.274	u51	-2.656	u76	-4.065
	(2.243)		(3.363)		(5.523)		(7.735)
u2	1.642	u27	-1.337	u52	-2.708	u77	-4.132
	(1.401)		(3.461)		(5.604)		(7.840)
u3	1.284	u28	-1.399	u53	-2.760	u78	-4.201
	(0.914)		(3.557)		(5.685)		(7.949)
u4	1.015	u29	-1.460	u54	-2.812	u79	-4.272
	(0.637)		(3.652)		(5.767)		(8.060)
u5	0.796	u30	-1.520	u55	-2.864	u80	-4.344
	(0.568)		(3.746)		(5.849)		(8.175)
u6	0.610	u31	-1.579	u56	-2.916	u81	-4.419
	(0.662)		(3.838)		(5.931)		(8.293)
u7	0.447	u32	-1.637	u57	-2.969	u82	-4.497
	(0.826)		(3.928)		(6.013)		(8.414)
u8	0.301	u33	-1.695	u58	-3.022	u83	-4.577
	(1.006)		(4.018)		(6.096)		(8.541)
u9	0.168	u34	-1.752	u59	-3.075	u84	-4.660
	(1.185)		(4.107)		(6.179)		(8.672)
u10	0.0452	u35	-1.808	u60	-3.128	u85	-4.747
	(1.358)		(4.194)		(6.263)		(8.808)
u11	-0.0686	u36	-1.863	u61	-3.182	u86	-4.838
	(1.523)		(4.281)		(6.348)		(8.951)
u12	-0.175	u37	-1.918	u62	-3.236	u87	-4.933
	(1.680)		(4.367)		(6.432)		(9.101)
u13	-0.276	u38	-1.973	u63	-3.290	u88	-5.033
	(1.830)		(4.452)		(6.518)		(9.259)
u14	-0.371	u39	-2.027	u64	-3.345	u89	-5.140
	(1.973)		(4.537)		(6.604)		(9.427)
u15	-0.462	u40	-2.081	u65	-3.401	u90	-5.254
	(2.111)		(4.621)		(6.692)		(9.606)
u16	-0.548	u41	-2.134	u66	-3.457	u91	-5.376
	(2.243)		(4.704)		(6.780)		(9.798)
u17	-0.632	u42	-2.187	u67	-3.514	u92	-5.509
	(2.370)		(4.787)		(6.869)		(10.01)
u18	-0.712	u43	-2.240	u68	-3.571	u93	-5.655
	(2.493)		(4.870)		(6.959)		(10.24)
u19	-0.789	u44	-2.292	u69	-3.629	u94	-5.819
	(2.612)		(4.952)		(7.051)		(10.49)
u20	-0.864	u45	-2.345	u70	-3.688	u95	-6.005
	(2.728)		(5.034)		(7.144)		(10.79)
u21	-0.937	u46	-2.397	u71	-3.748	u96	-6.224
	(2.840)		(5.116)		(7.238)		(11.13)
u22	-1.008	u47	-2.449	u72	-3.809	u97	-6.493
	(2.950)		(5.197)		(7.333)		(11.56)
u23	-1.077	u48	-2.501	u73	-3.871	u98	-6.850
	(3.056)		(5.279)		(7.431)		(12.12)
u24	-1.144	u49	-2.552	u74	-3.934	u99	-7.414
	(3.161)		(5.360)		(7.530)		(13.01)
u25	-1.210	u50	-2.604	u75	-3.999		
	(3.263)		(5.441)		(7.631)		

Table: B.6: Estimated MTEs for oil beta

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	0.0488	u26	-0.545	u51	-0.780	u76	-1.021
	(1.482)		(2.088)		(3.406)		(4.767)
u2	-0.0473	u27	-0.555	u52	-0.789	u77	-1.032
	(0.992)		(2.147)		(3.456)		(4.832)
u3	-0.108	u28	-0.566	u53	-0.798	u78	-1.044
	(0.727)		(2.206)		(3.506)		(4.899)
u4	-0.154	u29	-0.576	u54	-0.807	u79	-1.056
	(0.588)		(2.263)		(3.556)		(4.967)
u5	-0.192	u30	-0.587	u55	-0.816	u80	-1.068
	(0.547)		(2.320)		(3.607)		(5.038)
u6	-0.223	u31	-0.597	u56	-0.825	u81	-1.081
	(0.575)		(2.376)		(3.657)		(5.110)
u7	-0.251	u32	-0.607	u57	-0.834	u82	-1.094
	(0.642)		(2.431)		(3.708)		(5.186)
u8	-0.276	u33	-0.616	u58	-0.843	u83	-1.108
	(0.727)		(2.486)		(3.759)		(5.263)
u9	-0.299	u34	-0.626	u59	-0.852	u84	-1.122
	(0.819)		(2.540)		(3.810)		(5.344)
u10	-0.320	u35	-0.636	u60	-0.861	u85	-1.137
	(0.911)		(2.593)		(3.861)		(5.428)
u11	-0.339	u36	-0.645	u61	-0.870	u86	-1.153
	(1.002)		(2.646)		(3.913)		(5.516)
u12	-0.357	u37	-0.655	u62	-0.879	u87	-1.169
	(1.090)		(2.699)		(3.965)		(5.609)
u13	-0.374	u38	-0.664	u63	-0.889	u88	-1.186
	(1.176)		(2.751)		(4.018)		(5.706)
u14	-0.391	u39	-0.673	u64	-0.898	u89	-1.204
	(1.259)		(2.803)		(4.071)		(5.810)
u15	-0.406	u40	-0.682	u65	-0.907	u90	-1.224
	(1.339)		(2.854)		(4.125)		(5.920)
u16	-0.421	u41	-0.691	u66	-0.917	u91	-1.244
	(1.417)		(2.905)		(4.179)		(6.039)
u17	-0.435	u42	-0.700	u67	-0.927	u92	-1.267
	(1.492)		(2.956)		(4.234)		(6.168)
u18	-0.449	u43	-0.709	u68	-0.937	u93	-1.292
	(1.565)		(3.006)		(4.289)		(6.310)
u19	-0.462	u44	-0.718	u69	-0.946	u94	-1.320
	(1.636)		(3.057)		(4.346)		(6.469)
u20	-0.475	u45	-0.727	u70	-0.957	u95	-1.352
	(1.705)		(3.107)		(4.403)		(6.650)
u21	-0.487	u46	-0.736	u71	-0.967	u96	-1.389
	(1.773)		(3.157)		(4.461)		(6.862)
u22	-0.499	u47	-0.745	u72	-0.977	u97	-1.435
	(1.838)		(3.207)		(4.520)		(7.124)
u23	-0.511	u48	-0.754	u73	-0.988	u98	-1.496
	(1.903)		(3.257)		(4.580)		(7.471)
u24	-0.523	u49	-0.763	u74	-0.998	u99	-1.592
	(1.966)		(3.307)		(4.641)		(8.019)
u25	-0.534	u50	-0.772	u75	-1.009		
	(2.027)		(3.357)		(4.703)		

Table: B.7: Estimated MTEs for crash risk

U_D	MTE	U_D	MTE	U_D	MTE	U_D	MTE
u1	-3.721	u26	0.581	u51	2.290	u76	4.031
	(4.596)		(6.111)		(10.15)		(14.30)
u2	-3.025	u27	0.659	u52	2.354	u77	4.115
	(3.046)		(6.294)		(10.30)		(14.50)
u3	-2.582	u28	0.736	u53	2.418	u78	4.200
	(2.160)		(6.473)		(10.45)		(14.70)
u4	-2.250	u29	0.811	u54	2.483	u79	4.287
	(1.637)		(6.650)		(10.60)		(14.91)
u5	-1.979	u30	0.885	u55	2.547	u80	4.377
	(1.416)		(6.824)		(10.76)		(15.12)
u6	-1.749	u31	0.958	u56	2.612	u81	4.470
	(1.447)		(6.995)		(10.91)		(15.35)
u7	-1.547	u32	1.030	u57	2.677	u82	4.566
	(1.635)		(7.165)		(11.07)		(15.57)
u8	-1.366	u33	1.101	u58	2.742	u83	4.665
	(1.895)		(7.332)		(11.22)		(15.81)
u9	-1.202	u34	1.171	u59	2.807	u84	4.768
	(2.180)		(7.497)		(11.38)		(16.06)
u10	-1.050	u35	1.241	u60	2.873	u85	4.875
	(2.469)		(7.661)		(11.54)		(16.31)
u11	-0.910	u36	1.309	u61	2.940	u86	4.988
	(2.754)		(7.823)		(11.69)		(16.58)
u12	-0.778	u37	1.377	u62	3.007	u87	5.105
	(3.031)		(7.984)		(11.85)		(16.86)
u13	-0.654	u38	1.445	u63	3.074	u88	5.230
	(3.298)		(8.143)		(12.01)		(17.16)
u14	-0.536	u39	1.512	u64	3.142	u89	5.361
	(3.556)		(8.301)		(12.18)		(17.48)
u15	-0.424	u40	1.578	u65	3.211	u90	5.502
	(3.805)		(8.458)		(12.34)		(17.81)
u16	-0.317	u41	1.644	u66	3.280	u91	5.653
	(4.045)		(8.614)		(12.50)		(18.18)
u17	-0.214	u42	1.710	u67	3.350	u92	5.818
	(4.278)		(8.770)		(12.67)		(18.57)
u18	-0.114	u43	1.775	u68	3.421	u93	5.999
	(4.503)		(8.924)		(12.84)		(19.00)
u19	-0.0185	u44	1.840	u69	3.493	u94	6.200
	(4.722)		(9.078)		(13.01)		(19.48)
u20	0.0742	u45	1.905	u70	3.566	u95	6.431
	(4.935)		(9.232)		(13.19)		(20.04)
u21	0.164	u46	1.969	u71	3.640	u96	6.701
	(5.143)		(9.385)		(13.36)		(20.68)
u22	0.252	u47	2.033	u72	3.716	u97	7.034
	(5.345)		(9.537)		(13.54)		(21.48)
u23	0.337	u48	2.098	u73	3.792	u98	7.476
	(5.543)		(9.690)		(13.73)		(22.54)
u24	0.420	u49	2.162	u74	3.870	u99	8.173
	(5.736)		(9.842)		(13.91)		(24.21)
u25	0.501	u50	2.226	u75	3.950		
	(5.926)		(9.994)		(14.10)		