UNIVERSIDAD DE MURCIA

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OPTION-BASED EXECUTIVE COMPENSATION AND RISK-TAKING BEHAVIOR

RETRIBUCIÓN DE DIRECTIVOS BASADA EN OPCIONES Y COMPORTAMIENTO FRENTE AL RIESGO

Dª. María Belda Ruiz

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RETRIBUCIÓN DE DIRECTIVOS BASADA EN OPCIONES Y COMPORTAMIENTO FRENTE AL RIESGO

TESIS DOCTORAL

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Porque no hay palabra en este mundo que me guste más,
nunca me cansaré de decir…
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TABLE OF CONTENTS

SUMMARY IN SPANISH (RESUMEN EN ESPAÑOL)

Uno de los cambios más relevantes que se han producido en las políticas retributivas de las grandes empresas cotizadas durante las últimas décadas es la utilización de opciones de compra sobre acciones, comúnmente conocidas como *stock options,* en los paquetes retributivos de sus altos directivos. La literatura previa ha generado importantes, pero contradictorias, evidencias sobre el efecto que las *stock options* provocan en el comportamiento frente al riesgo de los directivos. La teoría de agencia postula que estos planes de opciones reducen la aversión al riesgo de los directivos permitiéndoles participar en futuras ganancias debido a un aumento en el precio de cotización de las acciones de la empresa. Sin embargo, el modelo comportamental de agencia o *Behavioral Agency Model* (BAM) indica que las *stock options* pueden provocar el efecto contrario en la actitud frente al riesgo, ya que los directivos adoptarán una conducta más conservadora con el objetivo de proteger el valor intrínseco positivo de sus *stock options* (riqueza actual percibida).

En particular, las *stock options* proporcionan a los directivos incentivos para modificar el perfil de riesgo de la empresa a través de la sensibilidad de su riqueza (o valor de la opción) a las variaciones en el precio de las acciones de la empresa (delta) y a la volatilidad implícita negociada en el mercado (vega). Para conseguir la alineación de intereses entre accionistas y directivos en términos de niveles de riesgo deseados, se requiere un conocimiento preciso de estos incentivos y de su evolución cuando el comité de retribuciones diseña un plan con *stock options*. En este sentido, se necesitan modelos de valoración que se adapten a las particularidades que presentan las *stock options* para obtener conclusiones correctas sobre delta y vega y sus efectos en la actitud frente al riesgo de los directivos.

Centrándonos en estas particularidades, las *stock options* suelen emitirse en el dinero (*at-the-money*) y con un vencimiento a largo plazo, normalmente 10 años. Suelen tener un periodo de tiempo inicial, conocido como *vesting period*, durante el cual el ejercicio no está permitido. Una vez transcurrido ese periodo, los directivos pueden llevar a cabo el ejercicio anticipado de sus opciones en cualquier momento del tiempo. Si el directivo abandona la empresa de forma voluntaria o por ser despedido y esta salida ocurre durante el *vesting period*, las opciones se pierden. Pero si la salida de la empresa ocurre una vez terminado el *vesting period*, el directivo puede ejercer sus opciones. Además, las *stock options* no son transferibles y presentan restricciones de cobertura. Por ejemplo, los directivos no pueden realizar la venta en corto de acciones de la empresa ni comprar opciones *put* (opciones de venta). Por último, los planes de *stock options* pueden incorporar objetivos de rendimiento mínimo para poder ser ejercidos. Todas estas particularidades complican significativamente el problema de la valoración de *stock options* y de sus efectos incentivadores.

Además de usar modelos de valoración adaptados a todas estas particularidades, es necesario profundizar en el efecto que, a través de delta y vega, las *stock options* producen en el comportamiento frente al riesgo de los directivos. Para tal fin, es fundamental considerar el efecto moderador que puede tener el género del directivo, dado que numerosos estudios previos indican que las mujeres son más adversas al riesgo que los hombres. De la misma forma, si el objetivo es analizar la conducta frente al riesgo del equipo de alta dirección en su conjunto, es importante tener en cuenta el efecto moderador de la diversidad de género existente en la alta dirección. Asimismo, la posición que ocupa el directivo en el equipo de alta dirección, máximo directivo (CEO) versus otros altos directivos, podría influir en la actitud frente al riesgo motivada por las *stock options*, dado que numerosos trabajos evidencian que los CEOs suelen adoptar conductas más agresivas en términos de riesgo.

El objetivo de esta Tesis Doctoral es contribuir a esta línea de investigación analizando en detalle los incentivos creados por las *stock options*, delta y vega, a través de modelos que se adaptan a las particularidades de las mismas (Parte I, Capítulos 1 y 2), así como su influencia en el comportamiento frente el riesgo (Parte II, Capítulos 3 y 4). En esta segunda parte se tiene en cuenta el efecto moderador de la diversidad de género en la alta dirección, el género del directivo y la posición ocupada en la jerarquía organizativa. Debido a la disponibilidad de datos, los diferentes estudios que conforman esta Tesis Doctoral han sido llevados a cabo utilizando amplias muestras de grandes empresas cotizadas estadounidenses, concretamente aquellas incluidas en el S&P 1500, índice que comprende el S&P 500, el S&P MidCap 400 y el S&P SmallCap 600.

El primer capítulo de esta Tesis Doctoral versa sobre la problemática de la valoración de *stock options*. La mayoría de los estudios previos han utilizado el clásico modelo Black-Scholes (BS) para valorar las *stock options* y sus efectos incentivadores. Sin embargo, este modelo no tiene en cuenta las particularidades de las mismas. El modelo Cvitanic-Wiener-Zapatero (CWZ) nos ofrece una expresión completamente analítica para calcular el valor de las *stock options* y sus efectos incentivadores, capturando la mayoría de sus características. En este primer capítulo se realiza un análisis de sensibilidad consistente en el estudio de la evolución de los niveles de delta y vega frente a cambios en las características propias de las *stock options*. Con respecto a las características recogidas tanto en BS como en CWZ, se lleva a cabo una comparación entre los dos modelos, mientras que se utiliza el modelo CWZ sólo para aquellas particularidades no capturadas por BS. Además, debido a la falta de consenso existente en la literatura previa, en este capítulo se analiza empíricamente el efecto de la volatilidad implícita negociada en el mercado en las sensibilidades de la riqueza del directivo calculadas a través del modelo CWZ.

Los resultados obtenidos en este primer capítulo ponen de manifiesto que las investigaciones sobre *stock options* y sus efectos sobre el comportamiento frente al riesgo no son robustas a la utilización de diferentes modelos de valoración. Del análisis de sensibilidad llevado a cabo se desprende que el modelo BS sobrevalora la influencia en delta y vega de la mayoría de las características de las *stock options*. Pero las mayores diferencias entre BS y CWZ se encuentran cuando analizamos el tiempo al vencimiento y su efecto sobre delta y vega. La principal razón de estas diferencias es la presencia del *vesting period* que el modelo CWZ considera y BS no tiene en cuenta. Además, utilizando el modelo CWZ, los resultados muestran que el ejercicio anticipado y la probabilidad de salida de la empresa influyen en delta y vega y, por tanto, son particularidades que los modelos de valoración deben capturar. En relación a la segunda parte de este capítulo, a través del modelo CWZ, el estudio empírico llevado a cabo muestra que aquellas empresas que operan en mercados más volátiles, debido al alto coste de supervisión, retribuyen a sus directivos con mayores incentivos (mayores deltas y vegas) para que actúen conforme a los intereses de los accionistas.

Dentro de la primera parte de esta Tesis Doctoral, el segundo capítulo se centra en el impacto de la condición de rendimiento mínimo y el ejercicio anticipado en el valor e incentivos creados por las *stock options*. Las *performance-vested stock options* (PVSOs) son opciones que incluyen como requisito para poder ser ejercidas una condición de rendimiento mínimo, que normalmente suele estar definida como un determinado nivel del precio de cotización de las acciones de la empresa. Recientes estudios sugieren incluir condiciones de rendimiento mínimo para crear en los directivos mayores incentivos, pero estos incentivos dependen de cómo esa condición de rendimiento está establecida. Como extensión del primer capítulo, este segundo se centra en las PVSOs y proporciona un análisis de sensibilidad del valor de la opción y sus efectos incentivadores basado en la condición de rendimiento y teniendo en cuenta el ejercicio anticipado voluntario, que es aquel que no está relacionado con la salida de la empresa. Para ello, se utiliza el reciente modelo Wu-Lin (WL) por ser un modelo completamente analítico desarrollado para valorar PVSOs. Sin embargo, este modelo no tiene en cuenta ese ejercicio anticipado que depende de la voluntad del directivo. Por este motivo, con el objetivo de llevar a cabo un análisis de sensibilidad que nos ofrezca conclusiones más realistas, este capítulo incorpora el efecto del ejercicio anticipado voluntario en el marco de trabajo de WL.

Los resultados muestran que un incremento en el precio de cotización necesario para poder ejercer las PVSOs y llevar a cabo el ejercicio anticipado para menores niveles del ratio precio de cotización/precio de ejercicio está relacionado con un menor valor de las PVSOs. Asimismo, un incremento en esa condición de rendimiento mínimo está asociado con menores niveles de delta y mayores niveles de vega, por lo que proporcionaría a los directivos incentivos para llevar a cabo una conducta más arriesgada. Los resultados muestran que los niveles de incentivos dependen del *gap* entre la condición de rendimiento y el ratio precio de cotización/precio de ejercicio en el que los directivos deciden ejercer sus opciones de forma anticipada. De estos resultados se desprende la importancia de considerar el efecto del ejercicio anticipado que depende de la voluntad del directivo en el diseño de los planes de *stock options* sujetos a condiciones de rendimiento mínimo.

Una vez analizados en profundidad los incentivos creados por las *stock options*, ya en la segunda parte de esta Tesis Doctoral, el tercer capítulo propone una combinación de las perspectivas teóricas de la agencia y del BAM —a través de la sensibilidad de la riqueza del equipo de alta dirección frente a cambios en el precio de las acciones (delta)— para aportar nuevas evidencias sobre el efecto de las *stock options* en la conducta frente el riesgo de los directivos. En este tercer capítulo, utilizando una amplia muestra de directivos pertenecientes a empresas incluidas en el S&P 1500 durante el periodo 2006-2011, se analiza la actitud frente al riesgo del equipo de alta dirección en su conjunto. No sólo el CEO es importante para el funcionamiento de la empresa, sino que el resto de directivos también son responsables de las políticas y estrategias que pueden alterar el nivel de riesgo de la empresa. Adicionalmente, debido a la mayor aversión al riesgo de las mujeres señalada por numerosos estudios empíricos, en este capítulo se considera el efecto moderador de la diversidad de género en el equipo de alta dirección en la relación entre *stock options* y nivel de riesgo de la empresa.

Utilizando el modelo CWZ para obtener los valores de deltas y vegas y después de controlar a través de varias metodologías el problema de endogeneidad, los resultados muestran que el comportamiento frente al riesgo del equipo de alta dirección no es lineal, encontrando una relación de U invertida entre la riqueza del equipo de alta dirección creada por las *stock options* y el nivel de riesgo de la empresa. Esta relación de U invertida se sustenta en la combinación de la teoría de agencia y del BAM. Cuando las opciones están fuera del dinero (niveles bajos de delta), prevalece el efecto positivo de la riqueza futura sobre la conducta frente al riesgo defendido por la teoría de agencia, mientras que a medida que el valor intrínseco de las opciones se incrementa (mayores niveles de delta), el efecto negativo de la riqueza actual percibida apoyado por los teóricos del BAM prevalece en el comportamiento frente al riesgo. Por tanto, el equipo de alta dirección se comporta de manera menos arriesgada a partir de determinados niveles de riqueza actual percibida. Por otro lado, de acuerdo con los estudios previos que muestran la mayor aversión al riesgo de las mujeres, los resultados señalan que aquellos equipos de alta dirección en los que hay presencia femenina adoptan una conducta más conservadora en comparación con los equipos formados exclusivamente por hombres. Estos equipos en los que existe diversidad de género soportan menos riesgo, por lo que el efecto negativo apoyado por el BAM está presente para menores niveles de riqueza actual percibida (menores deltas).

Por último, el cuarto capítulo de esta Tesis Doctoral, como una extensión del tercero, se centra en la relación de U invertida entre *stock options* y riesgo para analizar a través de muestras emparejadas las diferencias por razón de género en la actitud individual frente al riesgo de los directivos que son retribuidos con *stock options*. Por otro lado, la mayoría de estudios previos se han centrado en la relación entre *stock options* y riesgo limitando su alcance a la figura del CEO, sin considerar a los demás directivos que conforman el equipo de alta dirección. En este sentido, el mayor poder dentro de la empresa, los mayores niveles retributivos, la mayor responsabilidad y el mayor prestigio llevan al CEO a decantarse por proyectos más arriesgados en comparación con aquellos que llevarían otros directivos del equipo de alta dirección. Por ello, en este capítulo también se examina el efecto moderador de la posición que ocupa el directivo en el equipo de alta dirección en la relación entre *stock options* y riesgo.

Los resultados confirman la existencia de la relación de U invertida entre la riqueza creada por las *stock options* y el comportamiento individual frente al riesgo del directivo. En este capítulo se proporcionan nuevas evidencias consistentes con la mayor aversión al riesgo de las mujeres que ocupan puestos en la alta dirección en comparación con sus homólogos masculinos. El nivel de riqueza (nivel de delta) en el que se produce el cambio de una actitud arriesgada a un comportamiento menos arriesgado es inferior para el caso de las mujeres. La mayor aversión al riesgo lleva a las mujeres directivas a proteger su riqueza actual percibida con una conducta más conservadora. Asimismo, consistente con la literatura previa, los CEOs difieren de otros altos directivos en su actitud frente al riesgo cuando reciben *stock options*. Ese nivel máximo de riqueza de la relación de U invertida disminuye a medida que la categoría del directivo en el equipo de alta dirección desciende, lo que demuestra la mayor propensión al riesgo del CEO en comparación con el resto de miembros de la alta dirección. Además, los resultados indican que las diferencias de género en el comportamiento frente al riesgo son más significativas en los niveles más altos de la jerarquía, como es el caso del CEO.

En definitiva, las evidencias aportadas a lo largo de los cuatro capítulos que componen esta Tesis Doctoral constituyen herramientas útiles para mejorar la gestión retributiva llevada a cabo por la empresa y facilitar el diseño de los planes de retribución con *stock options*. Los clásicos modelos de valoración de opciones financieras no son directamente aplicables para el caso de las *stock options*. Las empresas deberían implementar modelos de valoración que capturen las particularidades que presentan las *stock options* para retribuir a sus directivos con los niveles de incentivos adecuados de acuerdo con los objetivos de la empresa relacionados con el nivel de riesgo. Además, en relación al diseño de planes de opciones sujetos a condiciones de rendimiento mínimo, los comités de retribuciones deberían considerar la conducta de sus directivos relacionada con el ejercicio anticipado de sus *stock options* y, de acuerdo con dicha conducta, fijar las condiciones de rendimiento mínimo.

En relación al efecto de las *stock options* en el comportamiento frente al riesgo de los directivos, los comités de retribuciones deben tener en cuenta tanto el efecto positivo defendido por los teóricos de la agencia como el efecto negativo apoyado por el BAM. Tras una actitud de asumir riesgos, los directivos adoptan una conducta más conservadora cuando consideran que su riqueza actual percibida está en juego. Este cambio de actitud depende directamente de la aversión al riesgo de los directivos y, en este sentido, es fundamental tener en cuenta las diferencias existentes por razón de género y por la posición ocupada en la jerarquía organizativa.

Si el objetivo de la empresa es sumergirse en proyectos con valor actual neto positivo pero asociados con un incremento en el nivel de riesgo, los comités de retribuciones deberían llevar a cabo una política más agresiva de emisión de *stock options* para aquellos equipos de alta dirección en los que hay presencia femenina. Para evitar el rechazo a estos proyectos arriesgados, los planes de *stock options* de estos equipos de alta dirección deberían proporcionar mayores incentivos para asumir riesgos. De la misma forma, para liderar proyectos arriesgados a nivel individual, es necesario que los paquetes retributivos de las mujeres directivas proporcionen mayores incentivos para llevar a cabo una conducta más arriesgada. Por último, dado que los CEOs muestran una mayor propensión al riesgo cuando reciben *stock options* en comparación con otros directivos, los comités de retribuciones deben prestar una especial atención cuando diseñan los planes de *stock options* para estos máximos directivos con el objetivo de evitar efectos no deseados relacionados con una excesiva propensión al riesgo.

A partir de lo analizado en esta Tesis Doctoral, investigaciones futuras se centrarán en examinar otros aspectos que pueden moderar el comportamiento frente al riesgo creado por las *stock options*, como puede ser el caso de la edad, el nivel educativo o el tiempo que el directivo lleva ocupando su puesto en la alta dirección. Asimismo, además de considerar un horizonte temporal más amplio, se analizará si, en comparación con los directivos estadounidenses, los directivos de empresas situadas en otros países desarrollados presentan diferencias significativas en su comportamiento frente al riesgo cuando son retribuidos con *stock options*.

INTRODUCTION

From the perspective of agency theory, the separation between ownership and control that characterizes large traded firms and the existence of asymmetric information may result in a conflict of interests between executives and shareholders. Understanding corporate governance as the set of structures, internal policies and practices through which firms are operated and controlled, agency problems create thus the need for effective corporate governance. In fact, the main goal of a firm's governance structure is to contribute to the design of control mechanisms and incentives that help to align the actions and policies implemented by executives with the best interests of shareholders.

Executive compensation has been the subject of extensive research because it is an important mechanism of governance practices and it plays an important role in monitoring, maintaining and motivating executives to operate in shareholders' interests. Over recent decades, stock options have been included in executive compensation packages as a way to provide motivation for executives to act in the interests of shareholders and mitigate problems associated with executive risk aversion. Executive stock options (ESOs) are contracts that give the executive the right, but not the obligation, to buy a specified number of the firm's shares at a predetermined exercise price and for a predetermined period of time. Executives derive profit when the firm's stock price is above the exercise price at the time that the option is exercised. It is a singular compensation system that usually occurs among the members of the top management team (TMT) of large firms. In the 90s, there was an explosion in the use of stock options as part of executive compensation in the United States, and it later became common practice in many countries.

Linking long-term executive compensation with changes in shareholder wealth, stock option grants monitor and provide incentives to executives. The current literature that focuses on stock options has generated important, but contradictory, insights into the role that this form of compensation plays in encouraging executives to take risks. According to agency theory, as stock options allow executives to participate in future gains when the firm's stock price increases, this form of compensation encourages executive risk-taking behavior. However, more recently, the theoretical framework of the behavioral agency model (BAM) indicates that ESOs may produce the contrary effect because they create risk bearing (perceived wealth at risk) that negatively influences risk taking.

Considering either agency theory or BAM, what is clear is that researchers and practitioners continue to debate the risk implications of compensating executives with stock options. In particular, ESOs give executives incentives to alter the firm's risk profile through the sensitivity of executive wealth (or option value) to changes in the firm's stock price, or delta, and the sensitivity of executive wealth to changes in stock return volatility, or vega. Theoretical and empirical research on these risk taking incentives provided by ESOs, delta and vega, has received considerable attention in recent years. However, in order to align interests in terms of risk taking, precise knowledge of these incentives and their evolution are required when the board of directors, and specifically its compensation committee, designs stock option plans. In this regard, the use of an appropriate option valuation model that adapts, as far as possible, to the specific characteristics of ESOs is an extremely important issue in order to obtain right conclusions about delta and vega and their effects on executive risk taking.

In particular, ESOs differ from exchange-traded options in several respects. Most ESOs are typically granted at-the-money, that is, with an exercise price equal to the firm's stock price at the grant date, and are usually long-term (up to 10 years). Moreover, ESOs cannot be exercised immediately after granting. They usually have an initial period of time (typically 3 years), during which exercise is not permitted. This period is called the *vesting* period. After vesting, executives can exercise the options at any time without having to wait until the maturity date. In fact, early exercise is a common practice among those executives who receive stock options in their compensation packages. On the other hand, if the executive leaves the firm voluntarily or involuntarily before vesting, the options are forfeited. But, if the leaving happens after vesting, the executive has a short period of time (typically up to 3 months) to exercise the options. Other features of ESOs are their non-tradability and the fact that ESO holders are restricted in relation to hedging their position through, for instance, short selling the firm's stock or buy puts on the firm. All these characteristics incentivize executives to exercise their options early. Finally, stock option plans may include a performance-vesting condition, which means that executives cannot exercise their options unless a certain threshold (normally defined in terms of the firm's stock price appreciation) is met. All these differences between ESOs and exchange-traded options significantly complicate the problem of valuing ESOs and their incentive effects.

In addition to using specific valuation models that capture the particularities of ESOs, it is necessary to advance understanding of the risk taking effect of ESOs, taking into account important aspects that may moderate executive risk-taking behavior. In this regard, gender may have an effect, since there is considerable empirical evidence that women are more risk averse than men. Moreover, previous studies show that higher female risk aversion is also present in top management positions. This difference in the level of risk aversion may lead male and female executives to differ in their risk taking behavior when they have a significant amount of stock options in their compensation packages. In the same way, if the risk taking behavior of the whole TMT as a group is analyzed, it is important to consider the effect of TMT gender diversity on the relationship between ESOs granted to management and firm risk taking.

On the other hand, the position that the executive holds in the top management level, that is, CEOs versus non-CEO executives, may also impact the risk taking motivated by ESOs. In this sense, previous studies have mainly focused on examining the risk taking effect of ESOs limiting their interest to the figure of the CEO. However, for instance, prior research points out that CEOs are significantly more optimistic and risk-tolerant than the general population and the power of CEOs may lead them to adopt more aggressive risk taking behavior in comparison with non-CEO executives. Consequently, it is important to examine whether the ESO risk taking effect also depends on the position held in the corporate hierarchy.

Thus, the main aim of this thesis is to examine in detail the sensitivities of executive wealth to stock price (delta) and stock return volatility (vega) by using appropriate ESO valuation models, as well as their effects on executive risk taking considering different theoretical perspectives and examining essential factors that may moderate such effects. The goal is to provide compensation committees with useful tools that facilitate the design of stock option plans. Due to data availability, this thesis has been conducted using wide samples of US firms that are included in the S&P 1500 index. This index is comprised of the S&P 500, the S&P MidCap 400 and the S&P SmallCap 600, which together cover approximately 90% of US market capitalization. Then, focusing on stock options granted to executives in large US firms, this thesis attempts to answer the following questions:

1. What is the impact of the characteristics of ESOs on delta and vega? Is this impact robust to the use of different ESO pricing models?

2. How does the firm's stock return volatility influence the design of ESO incentives?

3. How do the performance-vesting condition and voluntary early exercise affect delta and vega?

4. Drawing on agency theory and BAM, what is the effect of ESOs granted to the TMT on firm risk taking?

5. Does gender diversity in the TMT moderate the relationship between ESOs granted to management and firm risk taking?

6. Do female and male executives differ in their individual risk-taking behavior when they are compensated with stock options?

7. Does the executive's position in the corporate hierarchy influence the ESO risk taking effect?

All these specific questions are addressed in two parts in the thesis. The first, which includes Chapters 1 and 2, focuses on analyzing deltas and vegas through different valuation models. Chapters 3 and 4 are included in the second part, which examines the risk taking effect of these option incentives. This part combines the arguments of agency theory and BAM and considers the important moderating roles of TMT gender diversity, the gender of the executive and the position that the executive holds in the corporate hierarchy.

Chapter 1 addresses the first and the second question. Although the Black-Scholes (BS) model has been widely used in previous studies to value ESOs and their incentive effects, it does not take the main features of ESOs into account, and therefore the delta and vega values produced are not valid. The Cvitanic-Wiener-Zapatero (CWZ) model is an alternative model to BS for valuing ESOs. It has a closed formula and considers the main features of ESOs. Chapter 1 presents a sensitivity analysis to examine whether research on option-based compensation is robust when it uses different ESO pricing models. The sensitivity analysis consists of comparing the impact of the common parameters of the BS and CWZ models, as well as the effect of the specific features of ESOs captured in the CWZ model, on the sensitivity of executive wealth to stock price and volatility. In addition, through the CWZ model and using panel data methodology for a sample of 905 CEOs of S&P 1500 firms, an empirical analysis is developed to clarify the lack of consensus in the prior literature with respect to the influence of the firm's stock return volatility on CEO wealth sensitivities.

The third question is addressed in Chapter 2. A growing literature on the risk incentives that options provide to executives suggests including performance-vesting conditions in ESO plans. This literature shows that performance-vested stock options (PVSOs) provide stronger incentives than traditional stock options. However, the motivation capacity of PVSOs depends on how the perfomance target is established. Extending Chapter 1, Chapter 2 focuses on PVSOs and provides a sensitivity analysis of the PVSO value and incentives based on the performance-vesting condition and taking into account the executives' voluntary early exercise behavior. This chapter also examines the incentive effects of a real stock option plan. To do that, we use an extension of the Wu-Lin (WL) model, which is a fully analytical expression for valuing PVSOs. This extension incorporates the effect of exercising the options early at the executive's discretion, a feature which is not captured in the original WL model.

Chapter 3 addresses the fourth and the fifth question. This study proposes a combination of agency and BAM perspectives, specifically through the sensitivity of TMT wealth to stock price, to clarify the influence of ESOs on risk taking. This theoretical combination is supported empirically using panel data from six fiscal years on TMTs of the S&P 1500 firms and controlling for potential endogeneity issues through different methodologies. Moreover, since the unit of analysis in this chapter is the entire TMT, and due to the general view that women are both more risk averse and more loss averse than men, the risk taking effect of ESOs may change according to the female representation in the TMT. Therefore, this chapter also examines the moderating role of TMT gender diversity on the relationship between ESO grants and risk taking.

Extending Chapter 3, the last two questions are addressed in Chapter 4. In particular, using the sensitivity of executive wealth to stock price or delta to link the agency and BAM perspectives, and employing panel data methodology for matched samples of S&P 1500 listed firms, this study examines whether male and female executives differ in their individual risk-taking behavior when they receive stock options in their compensation packages. In addition to any possible gender effect, this chapter attempts to provide evidence as to whether CEOs and non-CEO executives react differently in terms of risk taking when they are compensated with stock options. In other words, this study also examines the moderating role of the position that the executive holds in the top management level on the ESO risk taking effect.

Finally, this thesis concludes with a summary of the main findings obtained from the four studies, their implications for executives' compensation policies and incentive design, and future lines of research.

PART I

STOCK OPTION INCENTIVES UNDER DIFFERENT VALUATION MODELS

CHAPTER 1

CHARACTERISTICS OF STOCK OPTIONS AND FIRM VOLATILITY*

* An earlier version of this chapter was presented at the following international conferences: the 4th Workshop of Risk Management and Insurance (Seville, 2011), the 50th Meeting of the Euro Working Group for Financial Modelling (Rome, 2012), the 4th International Finance and Banking Society Conference (Valencia, 2012), and the 7th Portuguese Finance Network Conference (Aveiro, 2012). Also, this chapter was presented at the seminar "*Are we using the wrong letters? An analysis of executive stock options Greeks*" held at Centre for Economics and Finance, University of Porto (Portugal) (July 2012).

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1.1. INTRODUCTION

A considerable variety of equity-based compensation forms, including stocks and stock options, exists for firms in search of providing executives with equity-based incentives. The evidence shows that the incentive effect on firm performance for compensation based on stocks is lower than that for stock options (Hemmer *et al*., 1999; Bryan *et al*., 2002). Thus, since the 1980s, stock options have become increasingly common in executive compensation packages of large firms (Hall and Murphy, 2003; Frydman and Saks, 2010; Murphy, 2013).

Executive stock options (ESOs) influence risk taking behavior through the sensitivity of executive wealth to stock price (delta) and the sensitivity of executive wealth to stock return volatility (vega). The majority of research studies have analyzed managerial incentives, delta and vega, using the standard Black-Scholes (1973) option pricing model (BS) even though it does not take into account the main characteristics of ESOs (long-term maturity, vesting period, early exercise, job termination risk, among others). Due to its analytical formula, the BS model is a possible choice in order to calculate the accounting fair value of ESOs.

However, as an alternative of the BS model, many ESO valuation models have been developed attempting to adapt to the particularities of ESOs. Among these pricing models, it highlights the Cvitanic-Wiener-Zapatero (2008) model (CWZ) for several reasons. First, the CWZ model captures most of the main characteristics of ESOs. In particular, this valuation framework considers: the long-term maturity of ESOs, the existence of a vesting period during which the exercise is not permitted, the common practice of early exercise (Bettis *et al*., 2005; Fu and Ligon, 2010), and the possibility that the executive leaves the firm during or after the vesting period. Second, unlike most of existing ESO valuation models, the CWZ model provides a completely analytical formula for pricing ESOs. Third, due to the need of an accounting standard in order to estimate the ESO fair value[1], the CWZ

[1] See the International Reporting Standard 2 (2004) (IFRS 2) and ASC 718 (formerly FAS 123R).

model could become such accounting standard because of its fully analytical solution.

The first aim of this study is to carry out a sensitivity analysis to examine whether research on option-based compensation is robust when it uses different ESO pricing models. The sensitivity analysis consists of comparing the CWZ sensitivities of executive wealth to stock price and stock return volatility with those of the BS to changes in their common parameters, which are the underlying stock price, time to maturity and volatility. This study also examines how delta and vega change with other CWZ parameters, not included in the BS model, which capture the particularities of ESOs. These parameters are the level of the barrier used to capture the early exercise, the decay rate of this barrier and the exit rate of executives which represents the likelihood of leaving the firm.

Moreover, the use of an inappropriate approach to calculate deltas and vegas could explain the empirical inconsistency shown in the prior literature about the effect of the firm's stock return volatility on executive pay-performance sensitivity, or delta (Core and Guay, 1999; Jin, 2002; Coles *et al*., 2006; Brockman *et al*., 2010). Then, the second aim of this study is to examine the influence of the firm's stock return volatility on the chief executive officer (CEO) incentives using both the BS and the CWZ model. To analyze this influence, we also take into consideration the impact of investment, diversification and financial policies on both delta and vega.

This study makes two major contributions to the literature. First, using the CWZ model, we respond to calls for further research of Hall and Murphy (2003), Lewellen (2006), Devers *et al*. (2007) and Goergen and Renneboog (2011) with respect to the limitations of using the standard BS model in order to value the stock options that top executives have in their compensation packages and their risk taking effects. For instance, Hall and Murphy (2003) and Lewellen (2006) indicate that the values calculated through the BS model are not correct to measure the incentives of undiversified executives. Goergen and Renneboog

(2011) point out several limitations when the BS framework is used for valuing ESOs, how can be the fact that it does not consider that executives can exercise their options before the maturity date, and the analytical expression of Cvitanic *et al*. (2008) does consider it. Due to the CWZ model takes into account the majority of the main characteristics of ESOs, we obtain right conclusions about the sensitivity of executive wealth to stock price and to stock return volatility. Second, we empirically clarify the inconsistency regarding the effect of the firm's stock return volatility on delta using, unlike previous studies, a more appropriate framework for valuing ESOs, particularly the CWZ model, and not only the BS model which is appropriate for valuing exchange-traded options but not for ESOs.

The remainder of this chapter is organized as follows. Section 2 provides a discussion of ESO risk taking effects and ESO valuation models. Section 3 briefly describes the delta and vega expressions based on the BS model and the CWZ model. Section 4 presents the parameters used in the sensitivity analysis. Section 5 reports the delta and vega sensitivity results. Section 6 provides the empirical analysis —data, sample, variables, analysis and results— of the effect of firm volatility on CEO wealth sensitivities. Finally, Section 7 presents the main conclusions of this chapter.

1.2. LITERATURE REVIEW

Executive risk-taking behavior and corporate decisions depend on the sensitivity of executive wealth to stock price, or delta, and on the sensitivity of executive wealth to stock return volatility, or vega. In particular, existing research is consistent with the view that higher vegas encourage executives' risk preferences (Guay, 1999; Rajgopal and Shevlin, 2002; Knopf *et al*., 2002; Low, 2009). But the relationship also runs in the other direction, that is, both delta and vega are affected by executive risk taking and corporate financial-investment decisions (Core and Guay, 1999; Coles *et al*., 2006; Brockman *et al*., 2010). In this regard, there is a lack of concluding remarks. Specifically, the impact of the firm's stock return volatility on delta is not clear due to while some researchers have presented a positive effect (Demsetz and Lehn, 1985; Core and Guay, 1999, 2002b; Coles *et al*., 2006; Brockman *et al*., 2010), other studies have found a negative association (Aggarwal and Samwick, 1999, 2002; Himmelberg *et al*., 1999; Jin, 2002). Thus, it is necessary to advance understanding by using an appropriate model for valuing these incentives.

1.2.1. Effects of delta and vega on risk taking

Many research studies have focused on examining the impact of ESOs on executive risk-taking behavior in response to their delta and vega values. They have found that the effects of both sensitivities on different corporate decisions are significant.

Specifically, several authors find that vega is significant in taking more risk. Rajgopal and Shevlin (2002) examine how stock option-based compensation influences executive risk-taking behavior for a specific sample of oil and gas firms. They find that higher vega leads to higher exploration risk and less hedging activities and remark that ESOs encourage executives to adopt risk-increasing behavior, which helps to reduce managerial incentive problems. Knopf *et al*. (2002) support the findings of Rajgopal and Shevlin (2002) regarding vega and hedging activities for a broader sample of firms. Moreover, they show a positive relationship between CEO delta and the use of corporate hedging activities. Coles *et al*. (2006) find that CEO vega exhibits a positive relationship with riskier policies, such as more (less) investment in R&D (property, plant and equipment), fewer operating segments and higher leverage. They find that delta values show the opposite effect, that is, higher delta is associated with low-risk policies. Later, Low (2009) examines the effect of equity-based compensation on the willingness of executives to take risk in response to the Delaware takeover regime during the 1990s. This researcher points out that higher vega encourages CEO to take more risk and, in relation to delta and risk taking, the research does not find conclusive findings.

With regard to financial decisions, Dong *et al*. (2010) observe that executives who are compensated with stock options are more likely to use debt rather than equity when their wealth is more sensitive to changes in stock return volatility. On the contrary, they show that delta does not have an influence on firm's financial choices. In this line, Cohen *et al*. (2000) focus on the effects of vega on executive risk taking and find a positive association between this incentive effect and both leverage and stock return volatility. Unlike Dong *et al*. (2010) and Cohen *et al*. (2000), Chava and Purnanandam (2010) point out that not only vega, but also delta affects corporate financial policies. Specifically, these researchers provide empirical evidence in support of both delta and vega effects by showing that higher CEO delta (vega) leads to lower (higher) firm leverage, which is in accordance with the findings of Coles *et al*. (2006). Focusing on the maturity structure of corporate debt, Brockman *et al*. (2010) show a positive relationship between CEO vega and short-maturity debt. However, they find a significant negative effect of CEO delta on short-maturity debt.

In line with the findings of Cohen *et al*. (2000) but without focusing on financial decisions, Williams and Rao (2006) use both a sample of mergers and a broader sample (firms from S&P 500, S&P MidCap 400 and S&P SmallCap 600) and also find a positive association between vega and stock return volatility, similarly to Guay (1999). More recently, Armstrong and Vashishtha (2012) examine the influence of delta and vega on total firm risk, and they distinguish between systematic and idiosyncratic risk. These researchers point out that both CEO delta and vega have a positive influence on total firm risk and its systematic component. However, while delta also affects positively on idiosyncratic risk, vega does not influence this risk component.

Finally, in relation to firm value, O'Connor and Rafferty (2010) examine the effect of the stock options that executives have in their compensation packages on shareholder value. After using GMM techniques to control for endogeneity problems, they find that there is a significant positive relation between delta and firm value, while vega does not have an influence on firm value.

1.2.2. Effects of the firm's risk profile on delta and vega

There are different corporate policies, such as investment, diversification and financial policies, which affect executive wealth sensitivities. In this line, Coles *et al*. (2006) indicate that riskier policies, particularly more investment in R&D, less capital expenditures, greater firm focus and higher leverage are associated with higher (lower) CEO vega (delta). Brockman *et al*. (2010) also examine the effects of these policies on CEO incentives and show that leverage and capital expenditure have a negative impact on delta and vega. Regarding R&D expenditure, they show similar results to Coles *et al*. (2006).

It must be emphasised that with respect to how stock return volatility affects managerial incentives, particularly the sensitivity to stock price, the empirical evidence on this relationship is inconclusive. On the one hand, several researchers have found a positive association. In this line, Demsetz and Lehn (1985) show that the volatility of firm's stock returns, or firm risk, leads to increase the pay-performance sensitivity. Core and Guay (1999) examine the effects of several corporate characteristics on delta and find that growth opportunities, CEO tenure, firm size and idiosyncratic risk have a positive influence on CEO delta. Core and Guay (2002b) also use the variance of returns and find that this variable is positively associated with the sensitivity of CEO wealth to stock price, taking market value and percent return variance as two separate independent variables. Coles *et al*. (2006) also point out that stock return volatility exhibits a positive relationship with CEO delta, as well as CEO vega. Following the framework of Coles *et al*. (2006), Brockman *et al*. (2010) show similar results. These findings are consistent with the view that when the firm's stock return volatility is higher or, in other words, when the environment in which the firm operates involves uncertainty, the cost of monitoring executives is also higher. In this case, executives require a stronger incentive to increase stock price in order to be motivated and act on behalf of shareholders.

On the other hand, other researchers have found the opposite effect: higher stock return volatility leads to lower pay-performance sensitivity. In this regard, Aggarwal and Samwick (1999, 2002) point out that the dollar return variance has a negative impact on the sensitivity of CEO wealth to stock price. This negative relationship supports the view that an increase in risk leads to an increase in the cost of providing executives with incentives. Himmelberg *et al*. (1999) also find that the firm's stock return volatility tends to decrease pay-performance sensitivity. Jin (2002), in addition to supporting the results obtained in the study of Aggarwal and Samwick (1999), considers both the systematic and idiosyncratic component of risk to analyze their effects on CEO incentives. This research indicates that idiosyncratic risk is negatively related to CEO pay-performance sensitivity. According to these researchers, higher idiosyncratic risk increases the cost of lost diversification of the CEO, and therefore the cost of providing equity-based incentives. This result is the same when CEOs can trade their market portfolios as well as when they cannot do so.

Thus, while some research shows that the firm's stock return volatility has a positive influence on delta, other studies find a negative effect. This inconsistency could exist as a result of the model used to measure CEO wealth sensitivities. Most previous researchers use delta and vega values based on the BS model incorporating the dividend yield, and the majority of recent studies also use the so-called "One-year approximation" method proposed by Core and Guay (2002). However, the BS model is not the most appropriate approach since, unlike the CWZ model, it does not take into account the main features of ESOs.

1.2.3. Executive stock option pricing models

The majority of research studies focused on examining the relation between ESOs and executive risk-taking behavior rely on delta and vega values from the BS model, even though ESOs and exchange-traded options are completely different. Alternative ESO pricing models have been developed taking into account some of the main features of this type of options.

In order to introduce the possibility of an early exercise in the BS framework, Jennergren and Näslund (1993) consider the first jump time of a Poisson process. They use a Poisson process as a proxy for all the reasons which lead executives to exercise their options before expiration and assume that the rate at which an employee can leave the firm depends on neither stock price nor time to maturity, which is known as constant intensity. Similarly to the BS framework, Jennergren and Näslund (1993) provide a partial differential equation subject to various conditions. As this early exercise depends on the underlying stock price and time to maturity, Carr and Linetsky (2000) develop an intensity-based framework to value ESOs. They suggest two simple analytical specifications as they separate the intensity or exit rate into two parts to measure the early exercise or forfeiture: a constant Poisson intensity parameter owing to the executive departure (voluntary or involuntary) and a random intensity one which depends on the stock price due to the need of liquidity or diversification.

Using binomial tree models, Huddart (1994) and Kulatilaka and Marcus (1994) propose a utility-based framework to capture the early exercise behavior. The utility–maximization approach is also used by Tian (2004) who calculates the certainty equivalent price of ESOs in order to examine the incentives for executives to maximize firm performance. The model developed by Hull and White (2004) is an extension of the binomial tree model for the valuation of ESOs. They use a barrier to capture the early exercise behavior of executives, that is, the exercise of vested options happens whenever the firm's stock price reaches a certain multiple of the exercise price. Ammann and Seiz (2004) propose a model that takes into account the early exercise by a simple adjustment of the exercise price. The exercise of the ESO takes place when the executive is satisfied with the intrinsic value estimated using the adjusted exercise price.

In addition to the probability of departure and early exercise, other models have taken into account that the volatility of the underlying asset varies with the time under a GARCH framework (Duan and Wei, 2005; León and Vaello-Sebastiá, 2009) or uncertain volatility (Brown and Szimayer, 2008). Other approaches have been developed in order to take other features of ESOs into consideration, which are the practice of resetting and reloading[2] (Brenner *et al*., 2000; Johnson and Tian, 2000; Corrado *et al*., 2001; Sircar and Xiong, 2007).

The model proposed by Cvitanic *et al*. (2008) (CWZ) provides a completely analytical solution, which is an advantage with respect to the Hull and White (2004) model. In contrast to Carr and Linetsky (2000), the CWZ formula does not require numerical integration assuming that ESO is vested. Furthermore, contrary to the binomial tree models which use a utility-based approach (Huddart, 1994; Kulatilaka and Marcus, 1994; Corrado *et al*., 2001), the CWZ model does not require parameters that are difficult to estimate, such as executive risk aversion.

Both Sircar and Xiong (2007) and Cvitanic *et al*. (2008) take most of the main characteristics of ESOs into consideration but, unlike the CWZ model, the valuation model of Sircar and Xiong (2007) does not have a fully closed expression. In particular, the CWZ model captures early exercise through a barrier, which is in advantage with respect to Brenner *et al*. (2000) and Johnson and Tian (2000) who do not consider the possibility of early exercise in spite of the fact that it is a common practice among executives (Huddart and Lang, 1996; Bettis *et al*., 2005; Fu and Ligon, 2010).

In summary, although no standard ESO pricing model has been established in the literature, the CWZ model could be considered a good candidate to become an accounting standard since its solution is completely analytical and it accounts for most of the main features of ESOs. It must be highlighted that the more ESO's characteristics the models take into consideration, the more accurate such models

[2]Reloading is the practice of granting more stock options to executives as a result of exercising the initial options that they have in their compensation packages (Dybvig and Loewenstein, 2003). Resetting refers to the practice of altering the terms of previously granted stock options prior the maturity date. The most common instance of resetting is the ''repricing'' of ESOs (Chidambaran and Prabhala, 2003), that is, firms lower the exercise price of ESOs when declining stock prices have moved ESOs out-of-the-money (Brenner *et al*., 2000; Corrado *et al*., 2001) due to after such drop, ESOs lose much of their value and their incentive effects (Sircar and Xiong, 2007).

become. Thus, we choose the CWZ model in order to obtain delta and vega values, from which we make comparisons with those obtained with the classical BS model.

1.3. DELTA AND VEGA BASED ON BS AND CWZ MODELS

Delta or, in other words, executive wealth sensitivity to stock price, is obtained as the rate of change of option value with the underlying stock price and vega, or executive wealth sensitivity to stock volatility, is obtained as the rate of change of option value with stock return volatility. Using the BS model for European call options, delta and vega have the following expressions:

$$\Delta = N(d_1)e^{-qT} \tag{1}$$

$$\nu = e^{-rT} S\sqrt{T} n(d_1) \tag{2}$$

where $N(\cdot)$ is the cumulative distribution function of a standard normal distribution, $n(\cdot)$ is its density function and the parameter d_1 is:

$$d_1 = \frac{ln(S/K) + (r - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}. \tag{3}$$

As the prior literature points out, the BS formula is useful for easily calculating the price of exchange-traded options but not for pricing ESOs because of their particularities. Cvitanic *et al.* (2008) develop an ESO valuation model from the point of view of the firm, because the firm is less constrained than the employee regarding risk diversification. Among their assumptions, their pricing model considers: a long-term maturity, a vesting period, the possibility of an exercise at any time after vesting and prior expiration (American style), the early exercise effect, and the obligation to exercise immediately (usually within the subsequent 90 days) if the executive leaves the firm during the live of the ESO, except if it happens before options are vested since in such case the options are forfeited. Other features of ESOs are not incorporated into this model because calculations would become extremely difficult. In particular, the possibility of resetting and reloading, the dilution effect and the possibility of default of the firm are not included.

Unlike Hull and White (2004), Cvitanic *et al*. (2008) derive an analytic pricing formula which computes the expected payoff of a call option that can only be exercised after the vesting period, T_0. In order to capture the effect of the executive's early exercise behavior, the CWZ model includes a decreasing barrier as maturity T approaches, such that, if the barrier is crossed when the option is vested, the option is exercised at that time. The rate of decay of the barrier is given by the parameter α and the level of the barrier at which the executive exercises their options is represented by L. Also, the CWZ model includes an exit rate which represents the likelihood of leaving the firm, voluntarily or because of being fire. It is denoted by λ and is the intensity of a Poisson process.

Under this scenario, the expressions of delta and vega are obtained as follows:

$$\Delta = \frac{\partial(K_{11} + K_{12} + K_{2} + K_{3})}{\partial S} \tag{4}$$

$$\nu = \frac{\partial(K_{11} + K_{12} + K_{2} + K_{3})}{\partial \sigma_{S}} \tag{5}$$

where K_{11} corresponds to exercising right after the vesting period, K_{12} captures the option exercise at the level L, K_2 corresponds to leaving the firm after the vesting period, and K_3 corresponds to exercising (or expiration) at maturity[3].

[3] The explicit formulas for K_{11}, K_{12}, K_2 and K_3 are provided in the Appendix A of this thesis.

1.4. PARAMETER SPECIFICATION

Delta and vega values depend on all parameters used to price ESOs, which are the current stock price, the exercise price, the time to maturity, the vesting period, the stock return volatility, the risk-free interest rate, the dividend yield, and the fictitious parameters used to represent the effect of early exercise and job termination risk. These parameters are the level of the barrier, its rate of decay as maturity approaches and the likelihood of leaving the firm.

We use a risk-free interest rate of 5% and a continuously compounded dividend yield of 2%, which is consistent with the prior literature. The value of the risk-free interest rate used in Carr and Linetsky (2000), Tian (2004), Cvitanic *et al*. (2008), Brown and Szimayer (2008) and León and Vaello-Sebastiá (2009) is also 5%. Bettis *et al*. (2005) use a risk-free rate of 5.58%, while Jennergren and Näslund (1993) use one of 8% and Core and Guay (2002) use one of 7%. Regarding dividend yield, Jennergren and Näslund (1993), Carpenter (1998) and Core and Guay (2002) use a stock's dividend yield of 3% while Bettis *et al*. (2005) use one of 0.14% and León and Vaello-Sebastiá (2009) include a continuously compounded dividend yield of 2.5%. We do not report sensitivity analyses for the risk-free interest rate and dividend yield since they have a little impact on delta and vega.

The evidence shows that the stock price and the exercise price are usually equal at the grant day, that is, ESOs are granted at-the-money (Bettis *et al*., 2005). For numerical purposes, we consider that the stock price and exercise price are equal to 1. Huddart and Lang (1996) show a mean value of the stock price to exercise price ratio when the options are exercised equal to 2.22, and Marquardt (2002) shows one equal to 2.17 and 1.91 when exercise is based on stock price and maturity, respectively. In our sensitivity analysis, we consider a wide range for the ratio of the stock price to exercise price, from 0.25 to 2.5. Obviously, the option is in-the-money (out-of-the-money) if this ratio is above (below) 1.

Concerning the firm's stock return volatility, we use an annualized volatility of 30% for the underlying asset since many existing studies use this value (Jennergren and Näslund, 1993; Carr and Linetsky, 2000; Core and Guay, 2002; Tian, 2004; León and Vaello-Sebastiá, 2009) or one close to it. For instance, Huddart and Lang (1996) show a mean volatility of 39.3%, Carpenter (1998) of 31%, Marquardt (2002) of 29.2% and Bettis *et al*. (2005) of 38.61%. Accordingly, in order to calculate the sensitivities of delta and vega to changes in stock volatility, we use a range for the stock return volatility from 20% to 60%.

The empirical evidence on values of vesting period and time to maturity is conclusive. Jennergren and Näslund (1993) assume that the time to expiration of ESOs is equal to 10 years with a 3-year vesting period. Huddart and Lang (1996) examine ESO grants and exercise records for eight companies listed on the NYSE. Their data set includes both 5-year and 10-year options with vesting periods range from 3 to 5 years. Carpenter (1998) considers a sample of ESO grants from 1983 to 1984 in 40 firms listed on the NYSE and AMEX, with a mean maturity of 5.83 years, ranging from 1.15 to 9.48 years, and a mean vesting period of 1.96 years. For a sample of 278 CEOs, Guay (1999) reports a mean time to maturity of 7.2 years, ranging from 1.5 to 16.5 years. Core and Guay (2002) assume a 3-year vesting period at the grant day. Marquardt (2002) shows a mean maturity of 8.93 years (for a final sample of 57 firms and 966 ESO grants over the period 1963-1984). Bettis *et al*. (2005) and Cvitanic *et al*. (2008) assume a 10-year life with a 2-year vesting period while Leung and Sircar (2009) assume a 10-year maturity and a vesting period ranging from 2 to 4 years. Therefore, we consider a 10-year maturity with a 3-year vesting period.

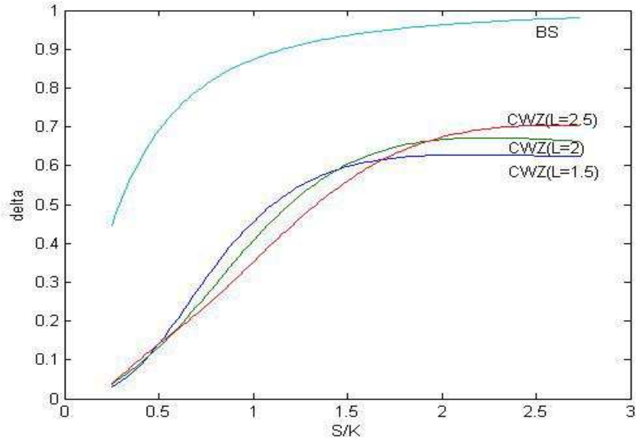
The CWZ model captures the early exercise after the option is vested with a fictitious barrier and the rate of decay of this barrier as maturity approaches, such that, if the barrier is crossed, the executive exercises the option at that time. As we chose a 10-year maturity and the barrier has to be over the exercise price, we use a mean rate of decay of the barrier equal to 2%, ranging from 0% to 4%. Also, we include three levels of the barrier, equal to 1.5, 2 and 2.5 times the exercise price since the evidence indicates that early exercise usually takes place when the stock price to exercise price ratio is around these values (Huddart and Lang 1996; Marquardt 2002).

Finally, we need to determine the probability of executive departure, which is reflected in the intensity of a Poisson process. Using a sample of large US firms (Fortune 500 firms) from 1992 to 2007 and considering both internal (board's decision) and external (merger or bankruptcy) CEO turnover, Kaplan and Minton (2012) report an average total CEO turnover of about 14.91% from 1992 to 1999 and about 16.78% from 2000 to 2007. Subsequently, Kaplan (2013) extends the time period analyzed in the study of Kaplan and Minton (2012) until 2010 and this recent research finds that the total CEO turnover from the period 1998-2003 and 2004-2010 is, on average, about 17.6% and 15.8%, respectively. Hence, according to such findings, we use a Poisson intensity of 16% and the sensitivities of delta and vega are calculated using values ranging from 14% to 20%.

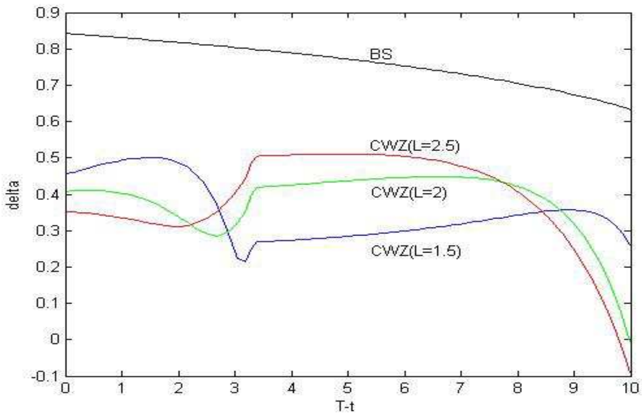
1.5. RESULTS

This section presents the delta and vega sensitivity results. Figure 1 illustrates the influence of the common parameters of the BS and CWZ models on delta. Those parameters are the underlying stock price (expressed as the ratio of the stock price to exercise price that measures the extent to which the option is in-the-money), time to maturity and stock return volatility.

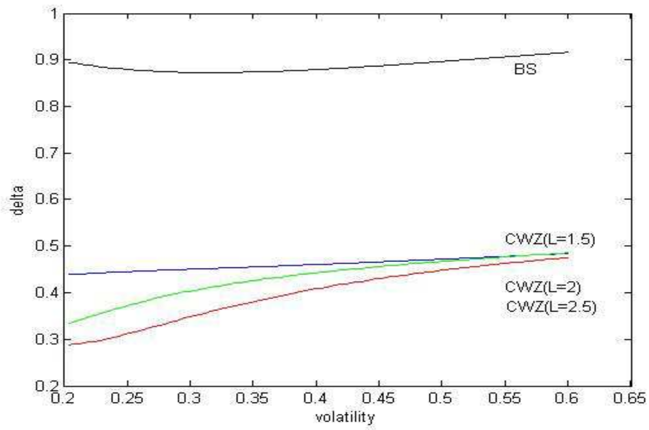
Figure 1. BS and CWZ delta sensitivity to the stock price to exercise price ratio, time to maturity and volatility



(a) Stock-to-exercise price

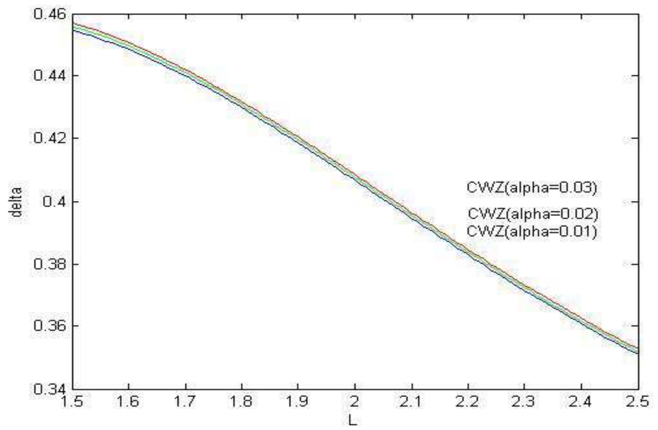


(b) Time to maturity

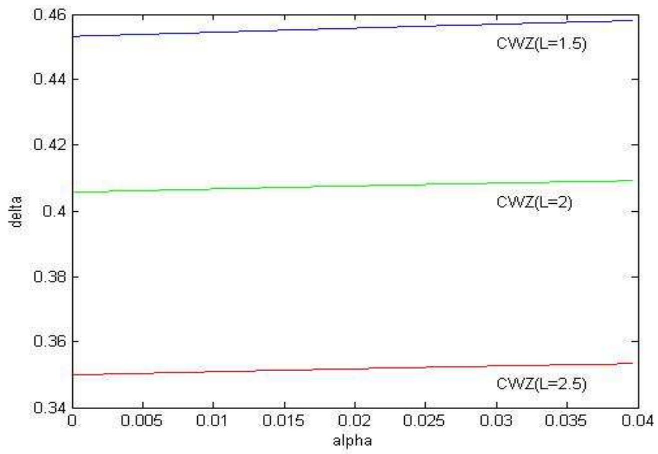


(c) Volatility

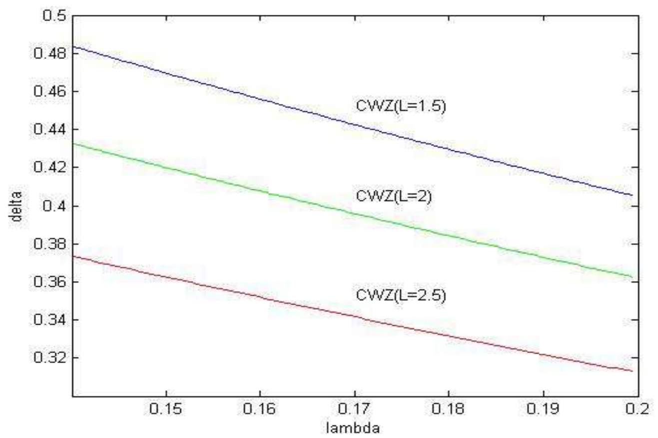
Figure 2. CWZ delta sensitivity to the level of the early exercise barrier, rate of decay of the barrier and probability of departure



(a) Level of the barrier



(b) Decay rate of the barrier



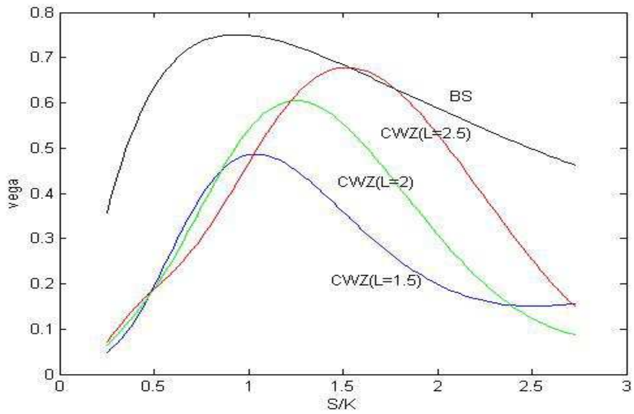
(c) Probability of departure

As Figure 1a shows, the BS model overvalues the influence of the stock price to exercise price ratio on the sensitivity of executive wealth to stock price, independently of whether ESOs are out-of-the-money or in-the-money. Consistent with Core and Guay (2002), delta increases with respect to the stock-to-exercise price and shows a decreasing rate of growth. In particular, the CWZ deltas are slightly below 0.5 when ESOs move out-of-the-money and vary between 0.5 and 0.7 when the stock price exceeds the exercise price. In other words, those ESOs that are deep in-the-money are very sensitive to changes in the firm's stock price, while out-of-the-money options are less sensitive to changes in stock price (Core and Guay, 2002). For the three levels of the barrier considered, delta values calculated through the CWZ model are significantly lower than the BS delta. Overall, these results show differences of values in level but the rank order is preserved (monotonic transformation), regardless of whether BS or CWZ deltas are used to examine risk taking effects. In sum, the BS delta and CWZ deltas behave similarly when we analyze how they change when the firm's stock price changes. Hence, both BS and CWZ deltas could be used indistinctly in order to examine their effects on executive risk-taking behavior or corporate investment-financial policies. However, this assertion would be completely true if the stock price was the single parameter that influences delta, but there are more parameters which could lead BS and CWZ deltas to behave differently, such as the time to maturity.

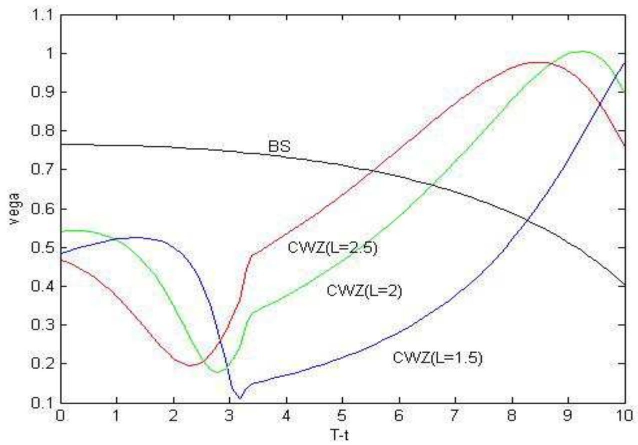
In contrast to Figure 1a, Figure 1b shows that the shape of the executive wealth sensitivity to stock price under the BS model when time to maturity changes is not a monotonic transformation of that under the CWZ model, although the overestimation of BS model continues to be present. The shapes of the BS delta and CWZ deltas are greatly different when the time to maturity changes. In particular, the BS delta is strictly decreasing as maturity approaches, while the CWZ deltas are U-shaped during the first years and concave after it. This difference is due to, unlike the BS model, the CWZ model incorporates the vesting period and assumes that ESOs can only be exercised after vesting. If the executive leaves the firm voluntarily or involuntarily before options are vested, ESOs are worthless. The impossibility of exercising the stock options that executives have in their compensation packages during an initial period of time reduces the managerial incentive to increase the firm's stock price. Consequently, after noticing that CWZ deltas behave completely different compared to the BS delta because of the presence of the vesting period, it is extremely important for firms to choose an appropriate ESO valuation model in order to obtain right conclusions of the effects of ESOs on executive risk-taking behavior and other corporate decisions. Contrary to the underlying stock price and time to maturity, Figure 1c shows that executive wealth sensitivity to stock price is almost not affected by changes in stock return volatility. Both the BS delta and CWZ deltas are nearly flat lines when the level of the barrier is equal to 1.5 (L=1.5), while at L=2 and L=2.5, CWZ deltas are uptrend lines, which quickly converge to the CWZ delta when L=1.5 (when the expected stock volatility is about 60%).

Figure 2 illustrates how the sensitivity of executive wealth to stock price changes with respect to the parameters which are considered in the CWZ model; in particular, the level of the barrier that captures the early exercise, the decay rate of this barrier and the probability of departure. Figure 2a shows that the executive wealth sensitivity to stock price decreases with the level of the barrier, and Figure 2b shows that it is not sensitive to the decay rate of the barrier. What Figure 2b means is that the incentive effect of ESOs to increase the firm's stock price is not affected by the fact that the executive is more likely to exercise their options the closer the maturity. However, the negative effect of the early exercise barrier on delta values highlights the importance of considering the common practice of early exercise for valuing ESO incentives properly. In this regard, the fact of not considering that ESOs are usually exercised early has been shown in the prior literature as a possible explanation for the higher BS values (Cvitanic *et al.*, 2008; Goergen and Renneboog, 2011). Finally, Figure 2c indicates that an increase in the probability of the executive leaving the firm, voluntarily or because of being fire, is associated with a decrease in the sensitivity of executive wealth to stock price. Thus, it can be stated that, in addition to the presence of the vesting period, the differences between BS and CWZ deltas could be due to the existence of an early exercise and job termination risk.

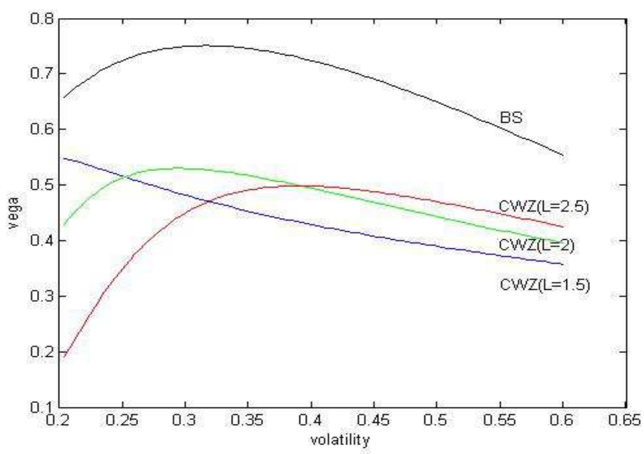
Figure 3. BS and CWZ vega sensitivity to the stock price to exercise price ratio, time to maturity and volatility



(a) Stock-to-exercise price

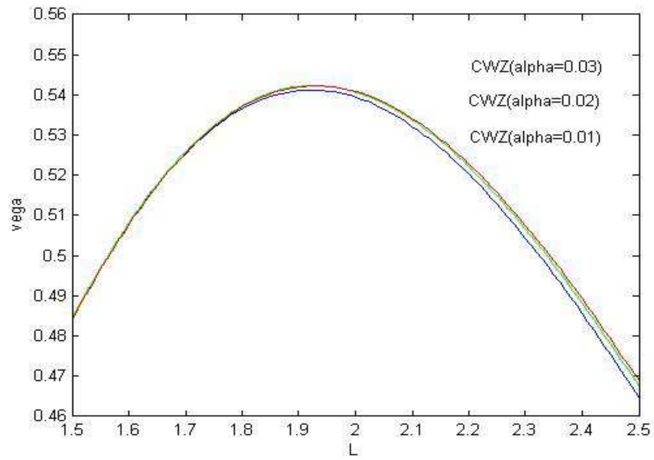


(b) Time to maturity

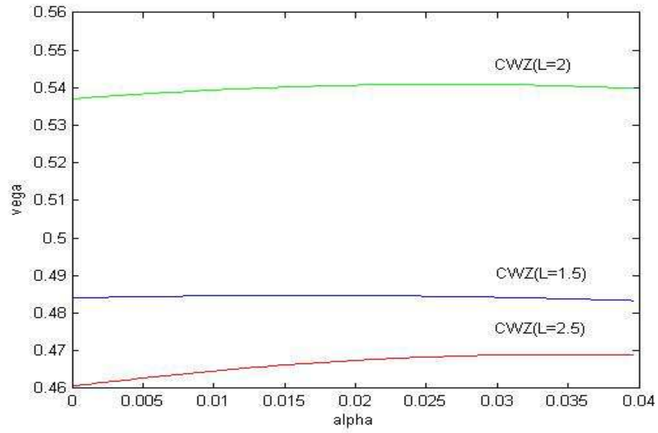


(c) Volatility

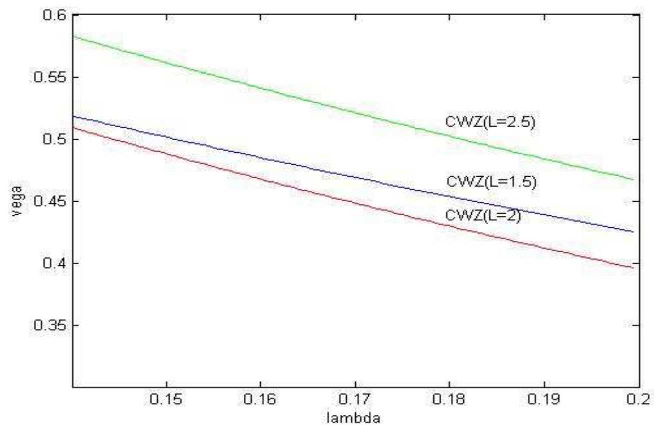
Figure 4. CWZ vega sensitivity to the level of the early exercise barrier, rate of decay of the barrier and probability of departure



(a) Level of the barrier



(b) Rate of decay of the barrier



(c) Probability of departure

Concerning the sensitivity of executive wealth to stock return volatility, while Figure 3 illustrates how it varies when the common parameters of the BS and CWZ models change, Figure 4 focuses on the specific parameters of the CWZ model. Figure 3a shows that the largest BS vega exists when the ESO is at-the-money, and when the ESO goes out-of-the-money or in-the-money the BS vega is lower. Again, the BS model overvalues the executive wealth sensitivity to stock volatility. Similarly, Core and Guay (2002) show that as options move in-the-money, the sensitivity of executive wealth to stock volatility decreases. In this regard, Low (2009) points out that the lowest vegas take place when the stock-to-exercise price is around 2.2. Unlike the maximum vega value of the BS model, the maximum vega values of the CWZ model appear as the ESO moves in-the-money; in particular, when the stock-to-exercise ratio is between 1 and 2, which is also consistent with Low (2009) who finds a stock-to-exercise ratio of 1.5 for the highest vega. In these situations, executives will adopt risk-increasing behavior due to the evidence shows that large vegas encourage executives to take more risk (Guay, 1999; Rajgopal and Shevlin, 2002; Williams and Rao, 2006; Chava and Purnanandam, 2010).

Similarly to the case of delta, Figure 3b shows that the CWZ vegas behave significantly different compared to the BS vega because of the presence of the vesting period. Specifically, the BS vega is decreasing as maturity approaches, and the CWZ vegas are decreasing during the vesting period, because ESOs cannot be exercised, and they start to increase when ESOs are vested. Moreover, the CWZ vegas decline when the maturity date is close. Then, in the same way as delta, due to BS and CWZ vegas differ significantly when we analyze the influence of the time to maturity, and therefore the vesting period, it leads us to highlight the importance of using an ESO valuation model that captures such characteristic in order to value the risk taking incentives correctly. Finally, Figure 3c shows that the BS vega and CWZ vegas decrease when the volatility is high and the overestimation of the BS model is clear. Overall, comparing the BS delta and vega with those obtained using the CWZ model with regard to changes in stock price and volatility, the results are consistent with the overvaluation of the BS model highlighted in the prior literature (Brown and Szimayer, 2008; Cvitanic *et al*., 2008; Goergen and Renneboog, 2011).

Figure 4a illustrates that an important factor that impacts on executive wealth sensitivity to stock volatility is the level of the barrier, that is, the presence of the early exercise. It can be seen that low and high levels of the barrier (L=1.5 and L=2.5) are associated with low values of CWZ vegas. Either the level of the barrier is low or high, executives do not have a strong motivation to make risky choices because, in the first case, the barrier can probably be reached and, in the second case, the most probable outcome is to end up below the barrier at expiration. Hence, although Figure 4b shows that the decay rate of the barrier does not influence the CWZ vegas, the practice of early exercise that the BS model does not consider is associated with the overestimation of this model (Cvitanic *et al*., 2008; Goergen and Renneboog, 2011). It can be concluded that the presence of the early exercise is a key factor that impacts on the executive wealth sensitivity to stock volatility because of the fact that it changes significantly as the level of the barrier varies. Finally, Figure 4c shows that as the probability of departure increases, the executive wealth sensitivity to stock volatility decreases, which reduces managerial incentives to take risky decisions.

1.6. EMPIRICAL ANALYSIS: THE EFFECT OF FIRM VOLATILITY ON CEO INCENTIVES

In this empirical analysis we examine the influence of the firm's stock return volatility on CEO wealth sensitivity to changes in stock price and CEO wealth sensitivity to changes in stock return volatility. To do that, we use the CWZ model as our main valuation model, but we also use the BS model in order to compare results. We also take into account some specific corporate policies, particularly investment, diversification and financial policies, which could affect CEO wealth sensitivities.

1.6.1. Data and sample

We use the Standard & Poor's ExecuComp database in order to obtain data on executive compensation. This database provides data on salary, bonus, total compensation, pension plans, as well as full details on executive stock and option awards for the top five executives of over 1,500 US publicly traded corporations (firms in the S&P 500, S&P Midcap 400 and S&P Smallcap 600). Furthermore, we use the Compustat database to obtain accounting data, segment data and stock return information.

In order to construct the sample, we consider those executives who are identified by ExecuComp database as CEOs (CEO indicates that this executive served as CEO for all or most of the indicated fiscal year). Rather than using common executives, we consider CEOs because most of the studies that analyze the effect of volatility on incentive design resulting in the lack of concluding remarks focus on the figure of the CEO. The final sample consists of an unbalanced panel of 905 CEOs, from which we take 2,623 CEO-year observations of options granted during the fiscal period 2006-2010.

1.6.2. Variables

Stock option incentives (DELTA and VEGA). In this analysis, we regress *DELTA* and V*EGA* on stock return volatility and measures of investment, diversification and financial policies. *DELTA* and *VEGA* measure CEO wealth sensitivities to stock price and stock return volatility, respectively. The expressions of delta and vega contain the following parameters: E is the exercise price of the option; T is the time to maturity; S is the price of the underlying stock at the end of each fiscal year available in ExecuComp during the sample period; σ is the expected annualized stock return volatility; r is the risk-free interest rate, estimated as the US Treasury-bond yield at 10-year constant maturity and q is the expected dividend rate, estimated as dividend yields every year during the sample period. With respect to the specific parameters of the CWZ model which are not included in the BS model, we consider the values used in the sensitivity analysis shown in Section 5 of this chapter.

Regarding time to maturity and exercise price, we consider the fact that a portfolio of options is made up of options granted in the current year (new grants) as well as previously granted options (exercisable or vested and unexercisable or unvested). Consequently, the delta and vega of a CEO option portfolio are equal to the sum of the deltas and vegas of both types of options. With respect to new options granted, ExecuComp provides information on time to maturity and exercise price allowing deltas and vegas to be computed straightforwardly and directly. Nevertheless, this database does not provide data relative to exercise price and time to maturity for previously granted options. Thus, we used the "One-year approximation" method developed by Core and Guay (2002) in order to estimate the exercise price and time to maturity for previously granted options. Many previous studies have used this approach together with the BS model (Core and Guay, 1999; Knopf *et al*., 2002; Rajgopal and Shevlin, 2002; Coles *et al*., 2006; Denis *et al*., 2006; Low, 2009; Dong *et al*., 2010; O´Connor and Rafferty, 2010; Tong, 2010; Brockman *et al*., 2010). Core and Guay (2002) highlight that this approach provides unbiased estimations of delta and vega, and these estimations are 99% correlated with the delta and vega values obtained if all the details of each option grant (or parameters) were available.

The method developed by Core and Guay (2002) considers two types of previously granted options, unexercisable (non-vested) and exercisable (vested) options. This is due to the fact that ExecuComp provides information on both types of options separately. In order to estimate exercise prices, Core and Guay (2002) use the average realizable value, which is the excess of stock price over exercise price and is available in ExecuComp. The number and fiscal year-end realizable value of new options are deducted from the number and realizable value of unexercisable options, respectively. This method divides the unexercisable and exercisable realizable values by the number of unexercisable and exercisable options, respectively. Finally, the exercise price is computed as the stock price minus the average in-the-money amount calculated in the previous step.

To estimate the time to maturity, Core and Guay (2002) take into account whether new options are granted or not. If the firm grants options in the current year, previously granted unexercisable options have a time to maturity equal to the time to maturity of such new grants minus one year, while the time to maturity of previously granted exercisable options is three years less than that of unexercisable options. If there are no new grants, the time to maturity of previously granted unexercisable (exercisable) options is equal to nine (six) years.

Stock return volatility (VOL). We measure the firm's stock return volatility as the standard deviation of monthly stock returns over a period of five years, that is, 60 monthly observations. Previously, Jin (2002) constructed his risk measure through the market model regressions using the 60 monthly observations immediately before the current year. Carpenter (1998) also estimates the stock return volatility for each firm using monthly data over the five years (60 observations) prior the grant date. Sanders and Hambrick (2007) include the stock price volatility as a control variable in their analysis and they measure it as the Black-Scholes volatility factor over 60 months.

Firm characteristics. Following Coles *et al*. (2006) and Brockman *et al*. (2010), we consider specific corporate policies through the following variables: *RD* is defined as research and development expenditure scaled by assets; *CAP* is defined as capital expenditure less sales of property, plant and equipment divided by assets; in order to measure the level of firm's diversification we use the variable *DIV* which is defined as the logarithm of the number of the firm's operating segments; *LEV* represents the leverage of the firm and is defined as total book debt divided by the book value of assets and, finally, we consider the logarithm of sales to control for firm size (*SIZE*), *CEO characteristics*. We also include in the models two variables related to specific attributes of CEOs in order to proxy for experience and the level of risk aversion: CEO tenure (*TENURE*) and CEO cash compensation (*CASHCOMP*), which are consistent with prior literature (Core and Guay, 1999; Rajgopal and Shevlin, 2002; Coles *et al.*, 2006; Brockman *et al.*, 2010). Accordingly, *TENURE* and *CASHCOMP* are measured as the logarithm of the number of years that the CEO has been occupying that high position and the sum of the CEO's salary plus bonus, respectively.

1.6.3. Analysis

We use panel data methodology in the analysis since it allows us to study the dynamics of cross-sectional populations. In this way, we improve the econometric specifications and the estimations because this methodology gives more information, more variability, less collinearity among the variables and more efficiency (Baltagi, 2001). In addition, firms and executives are heterogeneous, there are always characteristics of each firm or executive influencing delta and vega that are difficult to measure or hard to obtain. If this heterogeneity is not considered, the results may be biased. We control for unobservable heterogeneity in the panel data through an individual unobservable effect, η_i. Hence, the error term is $\varepsilon_{it} = \eta_i + \upsilon_{it}$, where υ_{it} is a random disturbance.

The relation between delta and vega and the aforesaid variables is explained according to the following panel data models:

$$\begin{aligned} DELTA_{it} &= \beta_0 + \beta_1 VOL_{it} + \beta_2 RD_{it} + \beta_3 CAP_{it} + \beta_4 DIV_{it} + \beta_5 LEV_{it} \\ &+ \beta_6 SIZE_{it} + \beta_7 TENURE_{it} + \beta_8 CASHCOMP_{it} + \eta_i + \upsilon_{it} \end{aligned} \quad (6)$$

$$\begin{aligned} VEGA_{it} &= \beta_0 + \beta_1 VOL_{it} + \beta_2 RD_{it} + \beta_3 CAP_{it} + \beta_4 DIV_{it} + \beta_5 LEV_{it} \\ &+ \beta_6 SIZE_{it} + \beta_7 TENURE_{it} + \beta_8 CASHCOMP_{it} + \eta_i + \upsilon_{it} \end{aligned} \quad (7)$$

We estimate these equations by taking into account the endogeneity problems highlighted in prior literature (Coles *et al*., 2006; Armstrong and Vashishtha, 2012). Ordinary least squares (OLS), within-groups or first-differenced OLS estimators are inconsistent when regressors are not exogenous and the Hausman test is not valid. The solution is to find instruments for the endogenous variables. The basic first-differenced two-stage least squares for panel data model proposed by Anderson and Hsiao (1981) is consistent for large panels. However, Arellano and Bond (1991) propose using Generalized Method of the Moments (GMM), in particular the first-differenced GMM estimator, which is asymptotically efficient and exploits more moment conditions that the one proposed by Anderson and Hsiao (1981). In order to test endogeneity we use the Hansen test. This test indicates whether the instruments are uncorrelated with the error term, an essential condition for the validity of the instruments.

1.6.4. Results

Panel A of Table 1 presents the mean values of delta and vega. As expected from the results shown in the previous sensitivity analysis, deltas obtained from the CWZ model are significantly smaller than those from the BS model for current-year granted options, previously granted unvested options and previously granted vested options. P-values for the Wilcoxon test allow us to reject equality of mean deltas in all cases. Regarding vega, the differences between BS and CWZ values are smaller than those for delta values but the differences continue to be significant. Panel B of Table 1 reports summary statistics for firm and CEO characteristics. Firm characteristics include the variables of diversification and investment-financial policies with mean values similar to those reported in previous studies (Coles *et al*., 2006; Brockman *et al*., 2010). CEO characteristics include CEO tenure and CEO cash compensation with mean values of 5.62 years and $1,069,400, respectively.

Table 1. Descriptive statistics

Panel A: Mean delta and vega and test of differences across the models

	BS	CWZ_L$_1$	CWZ_L$_2$	CWZ_L$_3$
Delta				
Current-year granted options	0.8192	0.4461* (0.000)	0.3891* (0.000)	0.3775* (0.000)
Previously granted unvested options	0.8873	0.6677* (0.000)	0.5760* (0.000)	0.5431* (0.000)
Previously granted vested options	0.8674	0.5472* (0.000)	0.5404* (0.000)	0.5660* (0.000)
Vega				
Current-year granted options	0.6272	0.4055* (0.000)	0.4165* (0.000)	0.4109* (0.000)
Previously granted unvested options	0.5312	0.4130* (0.000)	0.4234* (0.000)	0.4095* (0.000)
Previously granted vested options	0.4224	0.3893* (0.000)	0.5221* (0.000)	0.5760* (0.000)

Panel B: Firm and CEO characteristics

Variable	Mean	SD	10th percentile	Median	90th percentile
Firm Characteristics					
VOL[a]	35.13	18.71	19.40	32.25	52.20
RD[a]	3.69	3.08	005	2.92	9.25
CAP[a]	4.61	5.10	0.52	3.07	10.14
DIV[b]	0.96	0.69	0.00	1.10	1.79
LEV[a]	21.69	17.24	2.14	20.34	44.57
SIZE[b]	7.86	1.56	5.82	7.77	9.98
CEO Characteristics					
CASHCOMP[c]	1069.40	1142.80	486.22	899.02	1500.10
TENURE[b]	1.73	0.81	0.69	1.76	2.74

Panel A presents mean delta and vega values and p-values for the Wilcoxon test on the differences across the models are within parentheses. Panel B provides summary statistics on firm and CEO characteristics. See variable definitions in Section 1.6.2. BS: Black and Scholes (1973) model. CWZ: Cvitanic *et al.* (2008) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. SD: standard deviation. [a]: percentage. [b]: logarithm. [c]: $000s.

* Significant at 5%.

Table 2 reports the results of the effect of stock return volatility and investment, diversification and financial policies on delta. In the second column of this table we have used as the dependent variable *DELTA* calculated through the BS model, while in the third, fourth and fifth column we have used the CWZ model with a level of the early exercise barrier of 1.5, 2, and 2.5 times the exercise price, respectively. Table 3 also follows the same pattern. If we observe p-values of the Hansen test, the null hypothesis of the validity of the instruments is accepted, that is, there is no correlation between the instruments and the error term.

Table 2. GMM estimation of the influence of stock return volatility on delta

	DELTA BS	DELTA CWZ_L$_1$	DELTA CWZ_L$_1$	DELTA CWZ_L$_3$
VOL	0.152	0.108*	0.168**	0.157**
	(0.075)	(0.065)	(0.075)	(0.068)
RD	0.281	0.404**	0.481*	0.597**
	(0.265)	(0.156)	(0.250)	(0.260)
CAP	0.012	0.224	-0.098	-0.130
	(0.133)	(0.216)	(0.197)	(0.155)
DIV	-0.009	0.053	0.037	0.084
	(0.032)	(0.042)	(0.044)	(0.052)
LEV	-0.093	0.042	0.051	-0.149
	(0.078)	(0.102)	(0.127)	(0.140)
SIZE	0.093***	0.052***	0.054***	0.045***
	(0.006)	(0.008)	(0.008)	(0.009)
TENURE	0.047***	0.038**	0.027*	0.049**
	(0.009)	(0.018)	(0.015)	(0.021)
CASHCOMP	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Hansen p-value	0.195	0.913	0.625	0.506

See variable definitions in Section 1.6.2. BS: Black and Scholes (1973) model. CWZ: Cvitanic *et al*. (2008) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. Standard errors in parentheses.
*, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 2 shows that the firm's stock return volatility is positively and significantly related to the sensitivity of CEO wealth to stock price calculated through the CWZ model. The positive relationship is significant for the three levels of the early exercise barrier considered. These results provide evidence in support of that firms which are involved in an uncertain environment, measured by a high stock return volatility, have a higher monitoring cost, and therefore they need to motivate executives with higher incentives in order to align their interests to those of shareholders. Our findings about the effect of stock return volatility on delta support the results produced by Demsetz and Lehn (1985), Core and Guay (1999, 2002b), Coles *et al*. (2006) and Brockman *et al*. (2010) and contrast with the results of Aggarwal and Samwick (1999, 2002), Himmelberg *et al*. (1999), and Jin (2002). Most of these studies used the BS model in order to calculate CEO incentives. However, unlike CWZ delta values, our results regarding the impact of stock return volatility on delta calculated through the BS model are not significant. Thus, since the CWZ model is more appropriate for valuing the sensitivity of CEO wealth to stock price, this model allows us to clarify the lack of consensus existing in the prior literature supporting those studies which show a positive relationship.

In contrast to the significant relationship between stock return volatility and CWZ delta values, Table 2 shows that neither capital expenditures nor diversification-financial policies have a significant impact on the sensitivity of CEO wealth to stock price. Only R&D expenditure is positive and significant associated with CWZ deltas. Finally, CEO characteristics (tenure and cash compensation) are significant and have a positive impact on BS and CWZ deltas (Coles *et al*., 2006).

Table 3. GMM estimation of the influence of stock return volatility on vega

	VEGA BS	VEGA CWZ_L_1	VEGA CWZ_L_2	VEGA CWZ_L_3
VOL	0.506**	0.197**	0.144**	0.134**
	(0.256)	(0.092)	(0.059)	(0.053)
RD	0.290**	0.496**	0.591**	0.535**
	(0.138)	(0.199)	(0.268)	(0.251)
CAP	0.477	0.202	0.388	0.489
	(0.321)	(0.299)	(0.312)	(0.332)
DIV	-0.013	0.037	0.018	0.035
	(0.051)	(0.052)	(0.060)	(0.062)
LEV	0.226	0.105***	0.142**	0.325**
	(0.168)	(0.025)	(0.070)	(0.161)
SIZE	0.067***	0.041***	0.044***	0.045***
	(0.011)	(0.010)	(0.014)	(0.012)
TENURE	0.061***	0.005***	0.013**	0.026**
	(0.017)	(0.001)	(0.006)	(0.012)
CASHCOMP	0.003	0.008	0.007	0.008
	(0.005)	(0.009)	(0.005)	(0.007)
Hansen p-value	0.416	0.375	0.285	0.318

See variable definitions in Section 1.6.2. BS: Black and Scholes (1973) model. CWZ: Cvitanic *et al.* (2008) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. Standard errors in parentheses.
, * Significant at 5% and 1%, respectively.

Table 3 provides the results of the effect of the firm's stock return volatility and corporate policies on the sensitivity of CEO wealth to stock volatility. The impact of stock return volatility on vega values is stable regardless of the valuation model, that is, stock return volatility has a positive and significant influence on both BS and CWZ vegas. This seems to confirm the concluding remarks reached in the prior literature about vega, which is considered to be an essential variable of risk taking incentives. Specifically, many studies point out that the effectiveness of ESOs in encouraging executive risk taking depends on vega (Guay, 1999; Rajgopal and Shevlin, 2002; Knopf *et al*., 2002; Williams and Rao, 2006; Low, 2009). However, there is not much evidence in prior literature about the effect of the firm's stock return volatility on vega, except Coles *et al*. (2006) and Brockman *et al*. (2010) who, using the BS model, find that stock return volatility and risky corporate policies lead to higher sensitivity of CEO wealth to stock return volatility. Using the CWZ model, we also find this positive association.

As far as investment, diversification and financial policies are concerned, both the BS and CWZ model detect that R&D expenditure has a positive and significant impact on vega, similar to the results obtained by Coles *et al*. (2006) and Brockman *et al*. (2010). With regard to financial policy, we find that firm leverage only influences vega when we take into account the CWZ model; higher leverage is significantly associated with higher CWZ vega values. Using the BS model, Coles *et al*. (2006) point out similar findings. Also, the wealth of those CEOs with longer tenures is more sensitive to changes in the firm's stock return volatility, which will encourage them to take more risks.

Finally, the significant and positive relationship between firm size and both CEO wealth sensitivities is consistent with Brockman *et al*. (2010) who also find a positive association between firm size and delta and vega calculated through the BS model. These findings confirm the claim that larger firms monitor executives through higher incentives in order to reduce the classical agency problems that usually take place in such firms.

1.7. CONCLUSIONS

ESOs have become increasingly common in executive compensation over the last few decades. However, it is a controversial topic and disagreements exist regarding the impact of ESOs on executive risk-taking behavior, which may be caused by using an inappropriate model for valuing ESOs. In this study, we select the CWZ model to value ESO incentives, delta and vega, to compare them with those obtained using the BS model. We carry out a sensitivity analysis to show the influence of the stock price, time to maturity and volatility on delta and vega. Focusing on the results obtained, it can be concluded that the BS model greatly overvalues the influence of the stock price to exercise price ratio and stock volatility on delta and vega. But the biggest difference between the BS model and the CWZ model takes place when we analyze the influence of time to maturity on delta and vega due to the vesting period that, unlike the BS model, the CWZ model considers.

Moreover, using the CWZ model, we analyze the impact of early exercise and the probability of departure on delta and vega. Our findings show that the common practice of early exercise is a key factor that impacts on delta and vega, and therefore any model should consider it for valuing ESOs and their incentive effects correctly. Also, the findings indicate that associated with an increase in the executive probability of departure is a decrease in both delta and vega. On the other hand, using panel data methodology, this research offers new insight into the relationship between the firm's stock return volatility and incentive levels. In particular, the CWZ model produces a positive and significant relationship between stock return volatility and CEO delta, which clarifies the inconsistency shown in prior literature through the use of a more appropriate model for valuing ESOs.

In short, the findings show that research on option-based compensation and its risk taking effects is not robust to the use of different ESO pricing models. These findings can serve as a tool for firms to carry out an optimal incentive compensation design. In particular, in order to obtain right conclusions and provide executives with appropriate risk taking incentives, firms should implement an ESO valuation model that considers so important features such as the vesting period, the executives' early exercise behavior and the probability of executive departure.

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CHAPTER 2

VOLUNTARY EARLY EXERCISE AND PERFORMANCE-VESTED STOCK OPTIONS*

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2.1. INTRODUCTION

From the perspective of agency theory (Jensen and Meckling, 1976), stock options in executive compensation packages are seen as aligning the interests of executives to those of shareholders and mitigating problems associated with executive risk aversion. Specifically, stock options give executives incentives to alter the firm's risk profile through the sensitivity of executive wealth to changes in the firm's stock price (delta) and the sensitivity of executive wealth to changes in stock return volatility (vega) (Coles *et al*., 2006; Brockman *et al*., 2010; Armstrong and Vashishtha, 2012; Fargher *et al*., 2013).

A growing literature on the risk incentives that options give executives suggests including performance-vesting conditions in executive stock option (ESO) plans. In this way, the firm links the option vesting to the achievement of performance targets, normally defined in terms of the firm's stock price appreciation (Bettis *et al*., 2010). In comparison with traditional ESOs, the evidence shows that performance-vested stock options (PVSOs) create stronger incentives for executives to maximize shareholder value and stock return volatility (Johnson and Tian, 2000; Bettis *et al*., 2013). In fact, because of these greater incentives, it has been shown that while the use of traditional ESOs has declined, the use of PVSOs in executive compensation packages has increased considerably (Kuang and Qin, 2009; Bettis *et al*., 2013).

From a stock option valuation point of view, Wu and Lin (2013) provide a complete analytical model for pricing PVSOs. Because firms need to determine the fair value of stock option grants and attribute their cost in financial statements[1], the analytical model developed by Wu and Lin (2013) (WL) is a potential candidate to become an accounting standard in the particular case of PVSOs. Moreover, this closed form expression allows us to estimate the sensitivities of executive wealth to stock price and volatility, which is a useful tool for designing appropriate compensation packages in line with the firm's risk-related goals.

[1] See the International Reporting Standard 2 (2004) (IFRS 2) and ASC 718 (formerly FAS 123R).

In addition to the performance-vesting condition, Wu and Lin (2013) take into account most of the main characteristics that drive the value of ESOs: the long-term maturity, the vesting period, American type, and the possibility of early exercise when the executive leaves the firm (voluntarily or involuntarily) after the vesting period. In particular, job termination after vesting means that the executive cannot continue to hold their options and the right to exercise usually expires after 90 days after the date of job termination. In this case, the early exercise is not voluntary and is not related to the level of the firm's stock price or the moneyness of the options. However, executives usually decide to exercise their options early when they are deep in-the-money (Carpenter, 1998; Marquardt, 2002; Huddart and Lang, 1996; Bettis *et al*., 2005; Boyd *et al*., 2007; Brooks *et al*., 2012; Abudy and Benninga, 2013), because of the higher risk bearing created by positively valued stock options (Wiseman and Gomez-Mejia, 1998). In this way, executives collect the payoff (i.e., current wealth) in exchange for remaining the fewer possibilities for increasing their wealth in the near future (i.e., prospective wealth). This voluntary early exercise is captured by the analytical model developed by Cvitanic *et al*. (2008) (CWZ) but not by the WL model.

Due to the importance of considering the voluntary early exercise in order to examine the incentive effects of the PVSOs that executives receive as part of their compensation packages (Alvarez-Diez *et al*., 2014), the main goal of this study is to carry out a sensitivity analysis of the option value and option incentives, delta and vega, based on the performance-vesting condition and taking into account the executives' early exercise behavior. In addition, we analyze the incentive effects of a real stock option plan. To do that, we use an extension of the WL model incorporating the voluntary early exercise caused by the effect of the current and prospective executive wealth through an exogenous barrier. Consequently, this study contributes to the literature on both managerial incentives and stock option valuation. The fact of considering a valuation framework that adapts to the particularities of PVSOs allows us to advance understanding and obtain right conclusions of the incentives provide by this type of stock options.

The remainder of this chapter is structured as follows. Section 2 provides the extension of the WL model for valuing PVSOs. Section 3 describes the parameters used in the sensitivity analysis of PVSO incentives. Section 4 reports numerical results, including the sensitivity analysis of PVSO incentives and the real option programme. Finally, Section 5 presents the main conclusions of this study.

2.2. THE PVSO VALUATION FRAMEWORK

Based on the model developed by Wu and Lin (2013), namely the performance-vested and forfeiture-embedded employee stock option model, in this section we present the extended model for valuing PVSOs and their incentives. The extension of the WL model consists of the incorporation of the fact that options may be exercised early at any time after the vesting period at the executive's discretion[2].

2.2.1. The Wu-Lin (WL) model

Wu and Lin (2013) provide a completely analytical expression to price PVSOs considering, in addition to the vesting period, the possibility that the executive is fired or leaves the firm voluntarily before the option matures through a forfeiture (or exit) rate. This source of uncertainty is modelled through a Poisson process. In this model, based on the feature of attaching performance targets to the option vesting, the PVSO is effective (i.e., exercisable) only if the firm's stock price reaches the barrier B. Obviously, with the aim of creating the incentives described in the literature, this predetermined level B is set higher that the firm's stock price at the grant date (S_0), and is therefore higher than the exercise price K, since ESOs are usually granted at-the-money (Marquardt, 2002). In addition to the current stock price (S) and the time to maturity (T), this model includes the following parameters that capture some of the main features of ESOs: $[0, T_0]$ is the vesting

[2] As in the Black and Scholes (1973) setting, it is assumed that the stock price follows a lognormal process.

period (T_0<T), and λ_0 and λ are the intensities of leaving or being fired during and after the vesting period respectively.

The price of the option is the discounted call option payoff, $C_t = e^{-rt}(S_t - K)^+$, and the time when the option is exercised or expires is a random time, τ. As in Cvitanic *et al.* (2008) and Wu and Lin (2013), the conditional distribution of the exercise time is:

$$F(\tau) = 1 - e^{-\lambda_0 T_0 - \lambda(\tau - T_0)}, \quad \tau > T_0 \tag{1}$$

And the value of a PVSO in the WL model is equal to:

$$\begin{aligned} &K_1 + K_2 \\ &= e^{(\lambda-\lambda_0)T_0} E\left\{\int_{T_0}^{T} e^{-(r+\lambda)t}\left[(S_t - K)^+ I_{\left\{\underset{0\le u\le t}{Max}\, S_u \ge B\right\}}\right] dt\right\} \\ &+ e^{(\lambda-\lambda_0)T_0} E\left\{e^{-(r+\lambda)T}\left[(S_T - K)^+ I_{\left\{\underset{0\le u\le t}{Max}\, S_u \ge B\right\}}\right]\right\} \end{aligned} \tag{2}$$

where K_1 corresponds to leaving the firm at intensity λ after the vesting period, and K_2 corresponds to exercising (or expiration) on maturity. If the executive leaves the firm or is fired before the end of the vesting period, or the leaving occurs after the vesting period but without having reached the barrier B, the PVSO is forfeited. As the option cannot be exercised, executives obtain nothing from the option, and therefore these potential scenarios are not included in the above expression[3].

2.2.2. The WL model with an exogenous barrier

The analytical model of Wu and Lin (2013) can be employed to estimate the fair value of PVSOs. However, this model assumes that the early exercise happens if the executive leaves the firm after the vesting period, and ignores the possibility that executives may choose to exercise their options voluntarily before the

[3] The explicit formulas for K_1 and K_2 are given in the Appendix B of this thesis.

maturity date. In order to provide a more appropriate framework to value options that vest conditional on the stock price, it is necessary to include the feature of voluntary early exercise, since the empirical literature points out that executives exercise options early when they are deep in-the-money (Bettis *et al*., 2005; Abudy and Benninga, 2013; among others).

In this regard, Marquardt (2002) shows that executives decide to exercise their options when the firm's stock price is between 1.91 and 2.17 times the exercise price, considering that ESOs furthest in-the-money or closest to maturity are exercised first, respectively. Carpenter (1998) observes that the average ratio of the stock price to the exercise price at the time of exercise is 2.75 and that, on average, options are exercised 5.8 years after they were granted (all the options in her sample had lives of ten years). Across all exercises in their sample of 58,316 employees at eight firms, Huddart and Lang (1996) find that the early exercise of ESOs happens when the stock price is, on average, 2.2 times the exercise price. Later, Bettis *et al*. (2005) show that the ratio of stock price at exercise relative to the exercise price is 2.57, and options are exercised 2.41 years after vesting and 4.25 years before the maturity date. More recently still, Bahaji (2013) observes a mean stock price to exercise ratio at the exercise date of 2.46 and Abudy and Benninga (2013) find that, for their sample of Israeli firms and Israeli subsidiaries of major American firms, the voluntary early exercise of ESO grants takes place when the stock to exercise ratio is 2.96 and there are 4.84 years until the maturity date. This considerable empirical evidence is consistent with the idea that, as the perceived current wealth created by the stock options (or intrinsic value) increases, the risk aversion of the executive also increases (Wiseman and Gomez-Mejia, 1998; Larraza-Kintana *et al*., 2007). As a result, risk aversion leads executives to the early exercise of their options in order to collect the current wealth and avoid the risk of a possible drop in the firm's stock price.

Thus, the firm can control the executive's early exercise policy by assuming that early exercise happens when the firm's stock price is a certain multiple of the exercise price. With the aim of obtaining a more general approach that takes into account, in addition to the performance-vesting condition, the voluntary early exercise behavior and several other features of option grants, we extend the WL model including the exogenous barrier L in its framework, as in the analytical model developed by Cvitanic *et al.* (2008). We consider a decreasing barrier as maturity T approaches, $L_t = Le^{\alpha t}$, such that, if the barrier is crossed when the option is vested, the executive exercises the option at that point. The barrier decreases at a rate of decay represented by the parameter α (α<0), in order to capture the fact that early exercise is more likely to happen when there is less chance of increasing the executive wealth in the near future (i.e., the prospective wealth is low), and therefore executives prefer to collect the option payoff (i.e., current wealth).

While the barrier of the CWZ model is like capped-style options, the WL model is like up-and-in options, that is, the option is in effect if the firm's stock price hits the barrier B. Due to the existence of these two different barriers in the extension of the WL model proposed in this chapter, the time when the firm's stock price reaches the early exercise barrier L, denoted by T_L^0, differs from the time when the firm's stock price hits the performance-vesting barrier B, denoted by T_B^0.

$$T_L^0 = min\left\{t \in [T_0, T], S_t \geq Le^{\alpha(t-T_0)}\right\}. \tag{3}$$

$$T_B^0 = min\{t \in [0, T], S_t \geq B\}. \tag{4}$$

We consider that the vesting performance target is set below the point at which executives usually exercise their options early (L>B). If L<B, it is not reasonable to include the early exercise barrier in the valuation framework since executives cannot exercise their options at that point because the required performance has not been reached. Consequently, the time when the firm's stock price hits the decreasing barrier L is above the time when the required barrier stock price is crossed ($T_L^0 > T_B^0$). In addition, we denote by T_λ^0 the time of quitting/being fired independently of the option moneyness.

The time of exercise/expiry is:

$$\tau = min\left\{T_L^0, T_\lambda^0, T\right\}. \tag{5}$$

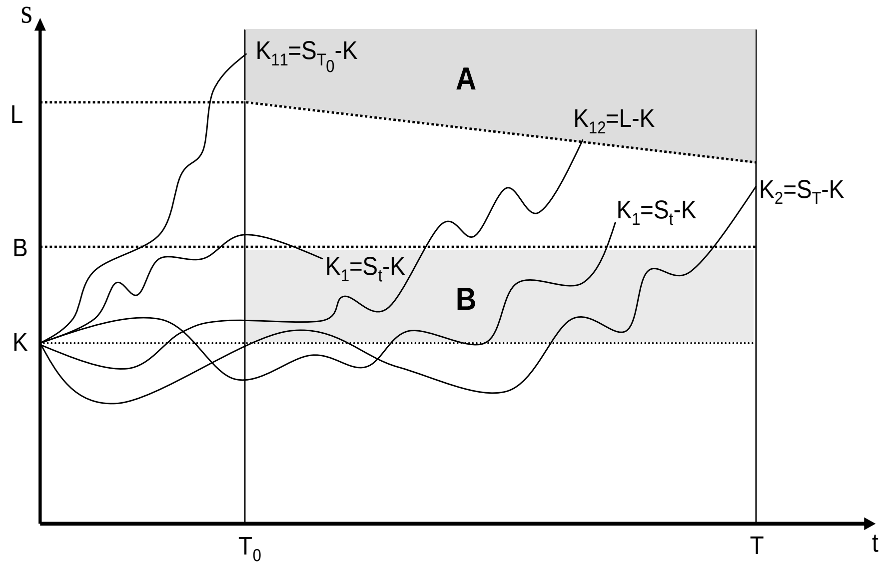
And, similar to Equation 2, the PVSO price is given by the following expression:

$$\begin{aligned}
&K_{11} + K_{12} + K_1 + K_2 \\
&= e^{(\lambda-\lambda_0)T_0} E\left[e^{-(r+\lambda)T_0}\left(S_{T_0} - K\right)^+ 1_{\left\{S_{T_0} \geq L_{T_0}\right\}}\right] \\
&+ e^{(\lambda-\lambda_0)T_0} E\left[\left(Le^{-\alpha T_0} e^{-(r_\alpha+\lambda)T_L^0} - Ke^{-(r+\lambda)T_L^0}\right) 1_{\left\{T_L^0 \leq T, S_T^0 < L_{T_0}\right\}}\right] \\
&+ e^{(\lambda-\lambda_0)T_0} E\left\{\int_{T_0}^{T} \lambda e^{-(r+\lambda)t}\left[\left(S_t - K\right)^+ 1_{\left\{T_L^0 > t, \underset{0\leq u\leq t}{Max} S_u \geq B\right\}}\right] dt\right\} \\
&+ e^{(\lambda-\lambda_0)T_0} E\left\{e^{-(r+\lambda)T}\left[\left(S_T - K\right)^+ 1_{\left\{T_L^0 > T, \underset{0\leq u\leq t}{Max} S_u \geq B\right\}}\right]\right\}
\end{aligned} \tag{6}$$

where K_{11} corresponds to exercising the PVSO immediately at the end of the vesting period and K_{12} captures the PVSO exercise at the level L after the vesting period. Both values are related to the voluntary early exercise above or at the desired level. On the other hand, K_1 corresponds to leaving the firm at intensity λ after the vesting period, and therefore the executive is forced to exercise the PVSO early, while K_2 represents the PVSO exercise (or expiration) at maturity date.

Figure 1 shows the probable scenarios with a positive payoff during the life of the option using the extension of the WL model. If the executive leaves the firm during the vesting period, the PVSO payoff will be zero. The PVSO expires in Region B if the executive is fired or leaves the firm voluntarily after vesting. In this case, as in the WL model, the option payoff in Region B will be S_t-K if and when the performance target is previously achieved, while in the CWZ setting the option payoff in Region B is always S_t-K. In contrast to the WL model which allows us to obtain a payoff in region A, we consider that L is the value at which the voluntary early exercise occurs because the current wealth is relatively high in comparison with the prospective wealth. Also, when the firm's stock price is above the level L at the time T_0, executives will exercise the option immediately.

Figure 1. The payoff structure of PVSOs taking the voluntarily early exercise into account



Thus, in the extended model proposed in this chapter, the CWZ model and the WL model are nested. As $L \to \infty$, that is, the firm's stock price cannot reach L_t ($T_L^0 > T$), K_{11} and K_{12} tend to zero. In this case, Equation (2) and Equation (6) give the same price and the WL model will be valid. On the other hand, when B=K, that is there is no performance-vesting condition, Equation (6) gives the same price as that obtained in the CWZ model.

2.3. PARAMETER SPECIFICATION

In order to obtain PVSO delta and vega values and carry out the sensitivity analysis, we require the basic inputs of classical option pricing models. These inputs are the exercise price and the stock price (or the stock price to exercise price ratio at the grant date), time to maturity, stock return volatility, interest rate and dividend yield.

To obtain real data on the stock-to-exercise ratio at the grant date and the time to maturity of new option grants, we focus on executives at the top management level in firms included in Standard and Poor's (S&P) ExecuComp database during the fiscal years 2006-2012. The dataset includes 1,162 publicly traded firms in the US (firms in the S&P 500, the S&P MidCap 400, and the S&P SmallCap 600 Indices) from which we obtain 25,340 executive-year observations. We also use the Compustat database as a source of data on firms' expected dividend yield and firms' monthly stock returns. Consistent with previous studies (Jin, 2002; Marquardt, 2002; Vieito and Khan, 2012), annualized volatility is obtained as the standard deviation of monthly stock returns over the previous 60 months immediately before the end of each fiscal year. Finally, the risk-free interest rate is estimated as the US Treasury-bond yield with a maturity of ten years.

Panel A of Table 1 reports descriptive statistics for all these parameters. As expected, most ESOs are issued with an exercise price equal to the firm's stock price at the grant date. In other words, ESOs are usually granted at-the-money (Rubinstein, 1995; Marquardt, 2002), and this is reflected in the mean value of 1 of the stock-to-exercise ratio at the grant date. Therefore, for numerical purpose, this study considers that the stock price and exercise price are equal to 100 at the grant date.

Concerning the length of the option's life, options are usually granted with 10-year lives and many studies assume this 10-year maturity (Jennergren and

Näslund, 1993; Hull and White, 2004; Bettis *et al.*, 2005; Cvitanic *et al.*, 2008; Leung and Sircar, 2009; León and Vaello-Sebastià, 2009, 2010; Alvarez-Diez *et al.*, 2014). Ranging from 1.5 to 16.5 years, Guay (1999) finds that the mean time to maturity for a sample of 278 CEO's options is 7.2 years. Later, Marquardt (2002) observes that, for a sample of 966 ESO grants, the mean (median) maturity is 8.93 (10) years. Similarly, Lee *et al.* (2007) find a mean (median) time to maturity of 8.85 (10.01) years. Although within the eight listed companies that Huddart and Lang (1996) use in their study there are options issued with 5-year lives, the majority of their dataset consists of 10-year options. Panel A of Table 1 shows that the descriptive statistics for our sample are consistent with previous studies, particularly a mean maturity of 8.99 years and a median maturity of 10.01 years. Therefore, we assume a 10-year maturity in our analysis.

Table 1. Descriptive Statistics

Panel A: Basic inputs

	Mean	SD	1st Q	Median	3rd Q
Stock-to-exercise ratio at the grant date	1.00	0.05	1	1	1
Maturity[a]	8.99	1.72	7.01	10.01	10.01
Dividend yield[b]	2.27	1.71	1.46	2.23	4.69
Volatility[b]	36.20	13.31	26.91	34.35	42.10
Risk-free interest rate[b]	3.58	0.83	3.22	3.26	4.63

Panel B: Stock price to exercise price ratio when ESOs are exercised

Year	2006	2007	2008	2009	2010	2011	2012	2006-2012
All executives (n=17559)	2.85	2.96	3.37	2.37	2.30	2.81	2.27	2.73
CEOs (n=3697)	3.08	3.27	3.45	2.42	2.39	2.76	2.40	2.86
Non-CEO executives (n=13862)	2.80	2.89	3.34	2.36	2.27	2.82	2.23	2.70

Panel A shows descriptive statistics for several parameters of new option grants. The stock-to-exercise ratio at the grant date and maturity are obtained from ExecuComp database. Dividend yield is the expected dividend yield obtained from Compustat database. Volatility is the standard deviation of the 60 monthly stock returns prior to each fiscal year-end. The risk-free interest rate is estimated as the US Treasury-bond yield at 10-year constant maturity. Panel B shows the mean stock-to-exercise ratio for our sample of option exercises, differentiating between CEOs and non-CEO executives. [a]: years, [b]: percentage. SD: standard deviation.

With regard to the volatility of the underlying stock, many previous studies assume a stock return volatility of 30% (Jennergren and Näslund, 1993; Carr and Linetsky, 2000; Core and Guay, 2002; Hull and White, 2004; Tian, 2004; León and Vaello-Sebastiá, 2009; Alvarez-Diez *et al*., 2014) and other researchers consider a volatility of 40% (León and Vaello-Sebastiá, 2010). Other empirical research shows values between 30% and 40%. In particular, Carpenter (1998) reports a mean volatility of 31%, Bettis *et al*. (2005) 38.61%, Huddart and Lang (1996) 39.3%, and Lee *et al*. (2007) 41.00%. In accordance with these findings, we find a mean stock return volatility of 36.20% for the US firms included in our sample, and we use this value in our sensitivity analysis of PVSO incentives.

As far as the risk free rate of interest is concerned, many previous studies have used a value of 5% in their analyses (Carr and Linetsky, 2000; Tian, 2004; Cvitanic *et al*., 2008; Brown and Szimayer, 2008; León and Vaello-Sebastiá, 2009; Alvarez-Diez *et al*., 2014). Because our study period is more recent, we use a mean value of 3.58% obtained from our sample of firms. With respect to dividend yield, the most common value used in prior research is 3% (Jennergren and Näslund, 1993; Carpenter, 1998; Core and Guay, 2002), while other studies have used the value of 2.5% (Hull and White, 2004; León and Vaello-Sebastiá, 2009) and 2% (Alvarez-Diez *et al*., 2014). Roughly in line with these values, we show and use a mean dividend yield of 2.27%.

In addition to all these parameters, it is necessary to estimate the parameters used to capture the specific characteristics of option compensation plans, which are the vesting period, the exit rate of executives, the level of the barrier L and its decay rate used to capture the early exercise, and the level of the barrier B that corresponds to the stock price target to option vesting.

Similar to the case of the time to maturity, there is a broad consensus on the vesting period and it is typically 3 years (Rubinstein, 1995). Although Bettis *et al*. (2005) and Cvitanic *et al*. (2008) consider a 2-year vesting period, Jennergren and Näslund (1993), Core and Guay (2002), and Alvarez-Diez *et al*. (2014) assume a 3-

year vesting period, and the vesting period considered in the study of Leung and Sircar (2009) ranges from 2 to 4 years. For their wide sample of option grants given to CEOs and other top executives of UK firms, Lee *et al*. (2007) find that the vesting period is universally set at 3 years. Thus, we consider a 3-year vesting period at the grant date in our analysis.

Regarding the probability that the executive leaves the firm (voluntarily or involuntarily), it is the intensity of a Poisson process and we follow the findings of the prior literature related to executive turnover to obtain an appropriate value of the exit rate of executives. In the real case studied in Cvitanic *et al*. (2008), these researchers consider an exit rate of 10%. However, they indicate that this estimation of the turnover rate is relatively low compared to average figures. Attempting to be more in line with the overall executive turnover, they also consider an exit rate of 15%. Consistent with this value, and considering both internal and external CEO turnover, the study of Kaplan and Minton (2012) points to an average total CEO turnover of about 14.91% from 1992 to 1999 and about 16.78% from 2000 to 2007 for a sample of large US firms (Fortune 500 firms). Later, Kaplan (2013) updates the data of Kaplan and Minton (2012) up to 2010 and observes that the total CEO turnover is, on average, 17.6% for the period 1998-2003 and 15.8% for the period 2004-2010. Thus, in line with these findings, and following the recent study of Alvarez-Diez *et al*. (2014), we consider an exit rate after the vesting period of 16%. It is reasonable to assume that the exit rate during the vesting period is below the exit rate after the vesting period, and therefore we consider a value of 1% in the former case (Wu and Lin, 2013).

With respect to the early exercise barrier, Panel B of Table 1 reports the mean value of the ratio of the stock price to the exercise price at the time of exercise for a sample of 1,880 firms included in Standard and Poor's (S&P) ExecuComp database during the seven fiscal years considered in Panel A. From this sample of firms, we take 17,559 executive-year observations of option exercises. As commented in Section 2 of this chapter, the empirical literature shows that the stock price to exercise price ratio when the ESOs are exercised early is equal to

2.22 (Huddart and Lang, 1996), 2.57 (Bettis *et al*., 2005), 2.8 (Carpenter, 1998), 2.96 (Abudy and Benninga, 2013), 2.46 (Bahaji, 2013) and 2.17 or 1.91 (Marquardt, 2002). Focusing on our sample, it can be observed that for the whole fiscal period of 2006-2012, and without differentiating between CEOs and non-CEO executives, the mean value of the stock to exercise ratio at the time of exercise is 2.73. Moreover, CEOs tend to exercise ESOs when they are deeper in-the-money compared to non-CEO executives. For numerical purposes, and consistent with prior literature and with the data shown in Panel B of Table 1, we consider two different levels of the exercise barrier: L = 2 and L = 3. We also assume a mean decay rate of the barrier of 1%.

Finally, we follow Wu and Lin (2013) as far as the stock price target to option vesting is concerned, and we consider three different levels, which are B equal to 1.2, 1.5, and 1.8 times the exercise price. In this way, we can examine how the incentive effects change with the level of the performance-vesting condition.

2.4. RESULTS

This section presents the numerical results. Table 2 provides PVSO prices taking into account different levels of the barrier that captures the desired voluntary early exercise of executives (L) and the performance-vesting barrier (B).

On the one hand, it can be observed that when the early exercise is less likely to happen (high-barrier L), the PVSO price is higher than the case of a low level of the early exercise barrier (Cvitanic *et al*., 2008). This pattern exists for the three cases of the performance target considered. On the other hand, an increase in the performance target attached to the option vesting is associated with lower PVSO prices, because of the greater difficulty in reaching the given performance target (Wu and Lin, 2013). Moreover, as expected, the PVSO value increases when the stock price moves closer to the target vesting price due to the higher likelihood of hitting the performance-vesting condition and obtaining the wealth from its exercise.

Table 2. Prices of PVSOs for different parameter values

α	S	L = 2		L = 2.5		L = 3	
		$T_0 = 1$	$T_0 = 3$	$T_0 = 1$	$T_0 = 3$	$T_0 = 1$	$T_0 = 3$
Panel A: B = 1.2							
0	80	10.0019	10.3239	11.0894	11.4207	11.6223	12.2501
	100	16.8556	18.7521	19.6193	19.8457	21.1327	21.3378
	120	23.9950	30.3007	28.7449	30.1399	31.9734	31.6536
-0.01	80	9.7703	10.2144	10.7840	11.3148	11.4033	12.1093
	100	16.2844	18.5298	19.0815	19.6084	20.5244	21.0610
	120	23.1743	29.9907	27.7054	29.6229	31.1141	31.2855
Panel B: B = 1.5							
0	80	8.9643	9.2317	9.9585	10.2665	10.4654	11.0803
	100	15.4759	17.4912	18.0639	18.5084	19.4932	19.9622
	120	22.6981	29.0926	27.2404	28.8361	30.3724	30.3211
-0.01	80	8.8117	9.1607	9.7189	10.1913	10.2999	10.9671
	100	15.0124	17.3114	17.6000	18.2978	18.9523	19.7137
	120	21.9930	28.8307	26.2882	28.3601	29.5770	29.9753
Panel C: B = 1.8							
0	80	7.3157	7.4354	8.1829	8.3395	8.6413	9.1133
	100	13.2952	15.1901	15.5406	15.9603	16.8195	17.3256
	120	19.9918	26.4744	24.0231	25.9680	26.6309	27.3635
-0.01	80	7.2184	7.4007	7.9920	8.2780	8.5271	9.0294
	100	12.9871	15.0710	15.1716	15.7842	16.3599	17.0953
	120	19.5276	26.2975	23.2440	25.5693	26.2195	27.0404

This table shows PVSO prices calculated from the model proposed in this study. The difference between Panels A, B and C is the performance-vesting barrier (B) considered. L: early exercise barrier. T_0: vesting period. α: rate of decay of L. S: level of moneyness. Other parameter values: K = 100; T =10; λ_0 = 0.01; λ = 0.06; σ = 0.3; r = 0.01.

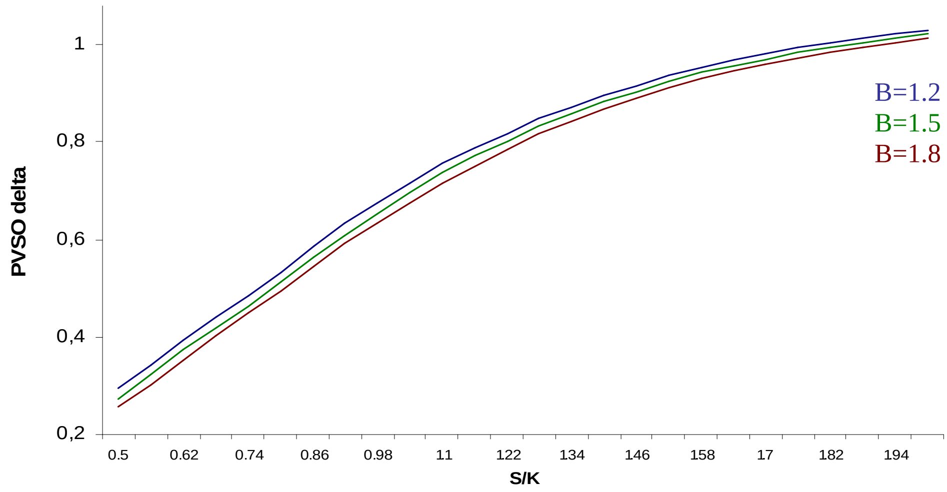
Table 2 also shows that if we consider an early exercise barrier which does not decrease (α = 0), the PVSO prices are higher than the cases of the decreasing barrier (α = -0.01). In this decreasing case, there is a high probability that early exercise takes place, which leads to a reduction in the PVSO value. As far as the impact of the vesting period on the PVSO price is concerned, we can see that the change in the vesting period from 1 year to 3 years affects the price of the PVSO positively. A possible explanation of the higher PVSO price when the vesting period is set to 3 years is that there is more time during which executives cannot exercise their options. Hence, the PVSO price increases facing the impossibility of exercising the option early. Moreover, it is possible that, after a longer vesting period, the firm's stock price exceeds the early exercise barrier and therefore the payoff obtained from exercising at T_0 will be higher.

2.4.1. Sensitivity analysis of PVSO incentives

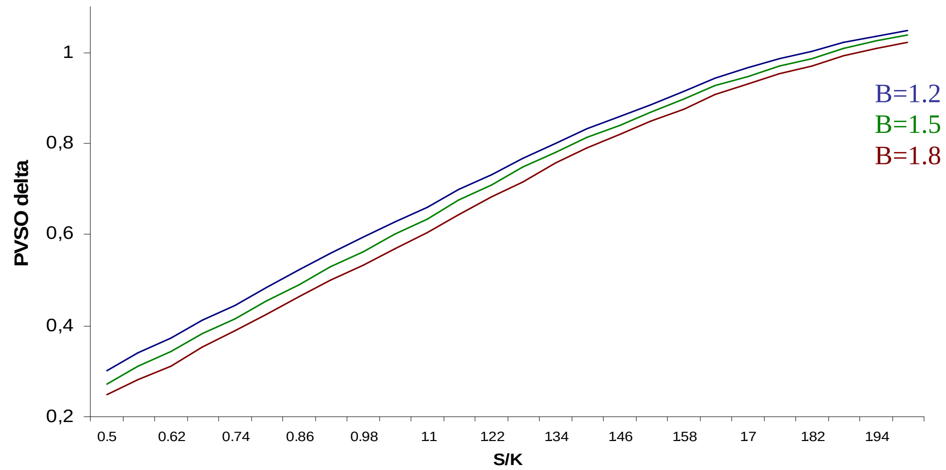
Figures 2 and 3 show the results from the sensitivity analysis of the incentive effects of PVSOs, delta and vega, using the parameter values defined in Section 3. Figure 2 shows the PVSO delta sensitivity to the stock price to exercise price ratio considering three different levels of the performance-vesting barrier. While Figure 2a takes into account a low early exercise barrier (L = 2), Figure 2b considers a higher level of the early exercise barrier (L = 3). This high-barrier L corresponds to a low risk aversion of executives, since the point at which they decide to exercise early is high. In other words, they do not resign themselves from obtaining a lower payoff and prefer to wait for an increase in the firm's stock price and therefore in their wealth.

As expected, in both figures, the sensitivity of executive wealth to stock price, or delta, increases with the moneyness of the PVSO. However, the performance-vesting barrier has a negative effect on the PVSO delta for both levels of executive risk aversion, L = 2 and L = 3. This means that when we consider the level of risk aversion in the PVSO valuation framework through the early exercise barrier as in Cvitanic *et al*. (2008), the increase in the performance-vesting condition reduces the PVSO delta, which is contrary to the evidence shown in previous studies of PVSOs and incentives (Johnson and Tian, 2000). However, the negative effect of the performance-vesting condition on PVSO delta is in line with those studies which point out that the higher incentives compared to those of traditional ESOs arise when performance targets are not set too difficult (Kuang and Suijs, 2006; Kuang and Qin, 2009). Accordingly, the increase in the performance-vesting barrier makes it more difficult for executives to exercise their options early, which, together with the executives' risk aversion, means that the incentive effect moves in the opposite direction. Finally, Figure 2a suggests that when the point at which executives decide to exercise early is higher, the negative effect of the performance-vesting condition is stronger, that is, the increase in the performance-vesting condition is associated with greater drops in the sensitivity of executive wealth to changes in the firm's stock price.

Figure 2. PVSO delta sensitivity to the stock price to exercise price ratio



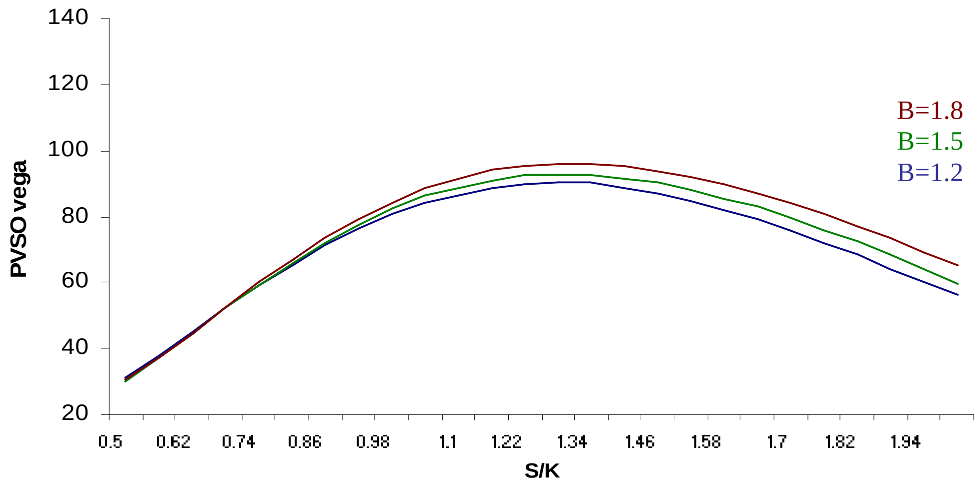
(a) Early exercise barrier equal to 2



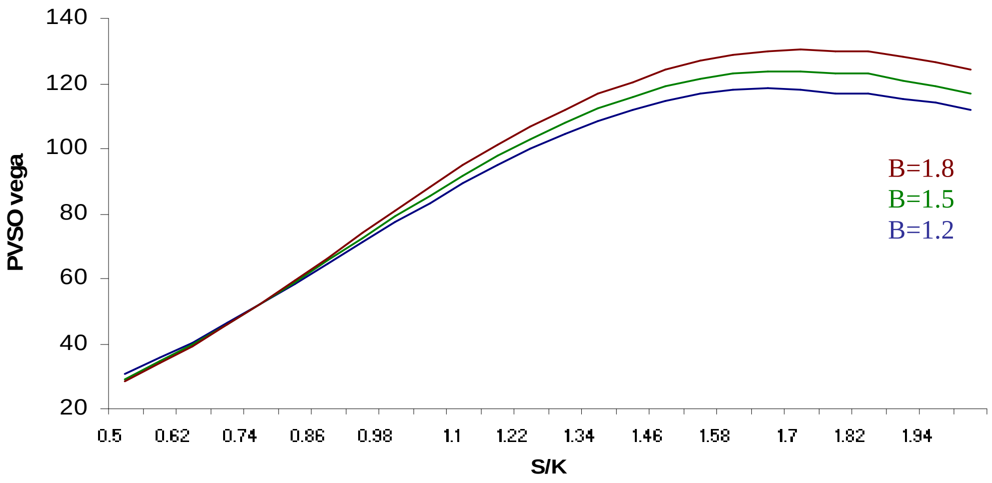
(a) Early exercise barrier equal to 3

Regarding the incentive to increase volatility or vega, Figure 3 shows that the PVSO vega increases with the moneyness of the option. However, when the stock price to exercise price ratio is high, the PVSO vega decreases. The reason for this inverted U-shaped relationship is that as the PVSO goes deep in-the-money, it is more likely to reach the early exercise barrier, and therefore a change in the firm's stock return volatility does not lead to higher increases in the PVSO price.

Figure 3. PVSO vega sensitivity to the stock price to exercise price ratio



(a) Early exercise barrier equal to 2



(a) Early exercise barrier equal to 3

Comparing Figure 3a and Figure 3b, we can observe that in the case of a low-level L, that is, when there is more risk aversion, the reduction in the PVSO vega takes place for lower values of the firm's stock price, which is caused by the higher probability of early exercise. As a consequence, when the PVSO is deep in-the-money, PVSO vega values corresponding to the low early exercise barrier are considerably lower than those of the high-level L. Finally, it can be seen that, contrary to the case of the PVSO delta, the performance-vesting condition has a positive influence on the PVSO vega, particularly when the option moves in-the-money, which may encourage executives to adopt risk-increasing behavior.

2.4.2. Case study

In this section, similar to Cvitanic *et al*. (2008) and Wu and Li (2013), we use the extension of the WL model to examine a real stock option scheme. We compare option prices, deltas and vegas calculated for different levels of the early exercise barrier and for different levels of the performance-vesting condition.

We use the data from Energen Corporation, a diversified energy firm with headquarters in Birmingham (Alabama) whose shares trade on the New York Stock Exchange (NYSE). It is a growing oil and gas exploration and production firm focused on increasing its production of oil and natural gas liquids in the Permian Basin in west Texas. This US listed firm had 3.3 billion barrels of oil-equivalent proved, probable, and possible reserves and contingent resources at the end of the year 2013. Approximately 82% of the reserves are in the Permian Basin, and the rest are in Colorado and the San Juan Basin in New Mexico[4]. The particular characteristics of this sector make it necessary to encourage executives take more risks in explorations. In this line, Rajgopal and Shevlin (2002) also focus on a sample or oil and gas producers to examine whether stock options provide executives with those incentives to undertake risky projects.

[4] Information obtained from the official website of the firm (www.energen.com).

Panel A of Table 3 provides details of two stock option plans granted to the top executives of Energen Corporation. Data on exercise price, time to maturity and vesting period are obtained from the firm's proxy statements and the ExecuComp database. As can be seen, these options are issued with an exercise price equal to the firm's stock price at the grant date (options are issued at-the-money). Moreover, the option grants have a vesting period of three years and expire after ten years. All these characteristics are common among stock option plans of US listed firms (Rubinstein, 1995). In this real case, the stock return volatility is estimated using the 60 monthly observations prior to each fiscal year-end, the dividend yield is obtained from Compustat, and the risk-free interest rate is the US Treasury-bond yield at 10-year constant maturity. We assume an exit rate of executives of 16%, which, as we have noted above, is consistent with the evidence from US firms (Kaplan and Minton, 2012; Kaplan, 2013).

Panel B of Table 3 presents the prices of the option grants, as well as delta and vega values. Since we do not have information about the policy related to the exercise of options adopted by the executives of Energen Corporation, we consider three different levels of the barrier used to capture early exercise (L = 2; L = 2.5, and L = 3), which is in line with the data observed in Table 1. The decay rate of the barrier considered is assumed to be 1%. Finally, as in the sensitivity analysis, we consider that the performance-vesting conditions are 1.2, 1.5 and 1.8 times the exercise price. Consistent with the results obtained in Table 2, while the early exercise barrier has a positive effect on the option price, this price reduces as the performance-vesting condition increases. Also, this table shows that the performance-vesting condition has a negative influence on the PVSO delta, which means that executives have a reduced incentive to maximize shareholder wealth.

Table 3. Option grants of Energen Corporation

Panel A: Basic information of option grants

No. of grant	Grant date	Expiration date	No. of options	S = K	T	T_0	σ (%)	q (%)	r (%)
1	1/23/2008	1/22/2018	117,370	60.56	10	3	19.27	0.64	3.66
2	1/27/2010	1/26/2020	165,694	46.69	10	3	28.51	1.17	3.22

Panel B: Prices, deltas, and vegas

		Prices			Deltas			Vegas		
No.	B	L = 2	L = 2.5	L = 3	L = 2	L = 2.5	L = 3	L = 2	L = 2.5	L = 3
1	1.2	1.0528	1.1665	1.2596	0.2253	0.2408	0.2542	37.8184	41.8960	46.3867
1	1.5	0.6972	0.7872	0.8631	0.2058	0.2176	0.2290	41.5644	44.7201	47.0107
1	1.8	0.4841	0.5354	0.5907	0.1813	0.1880	0.1961	43.7308	45.1674	47.9807
2	1.2	1.2576	1.3857	1.4706	0.2426	0.2476	0.2553	30.3314	30.6656	31.9065
2	1.5	0.9670	1.0721	1.1409	0.2245	0.2264	0.2321	32.1554	32.3502	32.8935
2	1.8	0.7682	0.8475	0.8999	0.2073	0.2080	0.2095	32.4586	32.7663	33.2542

Panel A presents the characteristics of two option grants of Energen Corporation. *No. of options*: number of options in the plan. *S*: stock price at the grant date. *K*: exercise price. *T*: maturity. T_0: vesting period of the options. σ: the firm's stock return volatility. *q*: annual dividend yield. *r:* risk-free interest rate. Panel B reports the prices, deltas and vegas of the option grants shown in Panel A. *L* and *B* are the early exercise barrier and the target vesting price, respectively. Prices are given in millions of dollars.

Focusing on delta values, we can see that the PVSO delta when B is low (B = 1.2) and L is high (L = 3) is around 25% (25.42% in the first grant and 25.53% in the second grant). On the other hand, when B is high (B = 1.8) and L is low (L = 2), the PVSO delta reduces (18.13% and 20.73% respectively). This means that the wealth of those executives who are less risk averse (L = 3) and receive options with a low level of the target vesting price (B = 1.2) is around 5% more sensitive to changes in the firm's stock price than those executives who are more risk averse (L = 2) and receive option grants with a higher level of the target vesting price (B =1.8). In particular, the incentive effect reduces approximately 40% in the first grant and 23% in the second grant. Finally, the increase in the performance-vesting condition and the decrease in the early exercise barrier move in the same direction, providing executives with lower deltas.

Although the increase in the performance-vesting condition is associated with lower option prices and option deltas, Panel B of Table 3 shows that increasing the level of the performance-vesting barrier increases the PVSO vega, which is consistent with the results shown in the previous sensitivity analysis. In addition, the PVSO vega increases when executives decide to exercise their options later, waiting for a higher level of the firm's stock price, and therefore indicating less risk aversion. In summary, increasing the performance-vesting condition and raising the early exercise barrier are associated with higher PVSO vegas.

2.5. CONCLUSIONS

The use of performance-vesting conditions in stock option plans has increased considerably since the evidence shows PVSOs create greater incentive effects than traditional stock options. In addition to the performance-vesting condition, other features of stock options that make them different from exchange-traded options (see Rubinstein, 1995), such as the common practice of exercising options early, make it essential to use appropriate valuation models to obtain precise knowledge of the incentives provided by PVSOs. In line with this argument, we conduct sensitivity analyses on option values and managerial incentives to increase stock price (delta) and stock return volatility (vega), based on the performance-vesting condition and the early exercise pattern observed in practice. These sensitivity analyses are carried out using the model recently developed by Wu and Lin (2013) for valuing PVSOs and incorporating the effect of the voluntary early exercise behavior by the addition of a decreasing barrier.

Our findings reveal that the increases in the performance-vesting condition and in the risk aversion of executives (lower exercise barrier) are associated with lower PVSO values. Also, we provide evidence about the impact of PVSOs on managerial incentives. In particular, the sensitivity analysis of the PVSO incentives indicates that the exercisable clause of options on the performance has a negative effect on the executive's incentive to increase the firm's stock price (delta), while it impacts positively on the executive's incentive to increase the stock return volatility (vega).

In order to provide the correct interpretations and implications of our results, we have to take into account that large vegas encourage executives to take more risk by, for example, investing in riskier assets or implementing a more aggressive debt policy (Guay, 1999; Rajgopal and Shevlin, 2002; Coles *et al*., 2006; Williams and Rao, 2006; Brockman *et al*., 2010; Armstrong and Vashishtha, 2012). In the case of delta, although the effect does not seem to be clear, most previous studies point out that the effect of increased delta is to expose executives to more risk, and therefore large deltas reduce the executive's appetite for risk (Knopf *et al*., 2002; Coles *et al*., 2006; Brockman *et al*., 2010; Fargher *et al*., 2013; Baixauli-Soler *et al*., 2014). Hence, if the firm increases the performance-vesting condition of the options granted to its executives, it may help to mitigate problems associated with executive risk aversion and encourage executives to undertake riskier projects, since PVSO delta reduces with an increase in the performance-vesting condition and PVSO vega increases with such vesting condition.

Our findings have important implications for compensation policies, highlighting the importance of considering both performance-vesting conditions and voluntary early exercise in order to value PVSO incentives properly. The level of incentives provided by stock option plans depends on the gap between the performance-vesting condition and the point at which executives decide to exercise the options early. In order to create the right incentives in relation to the risk-related goals, firms should take into account the early exercise behavior of their executives and, according to this behavior, set an appropriate performance target attached to the option vesting.

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PART II

EXECUTIVE RISK-TAKING BEHAVIOR: GENDER AND CORPORATE HIERARCHY

CHAPTER 3

STOCK OPTIONS, GENDER DIVERSITY AND FIRM RISK TAKING*

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3.1. INTRODUCTION

Stock options are a fundamental component of US executive compensation packages (Murphy, 2013). However, the evidence on how executive stock options (ESOs) affect firm risk taking is inconclusive. While some studies find that ESOs encourage executives to take more risk (Sanders and Hambrick, 2007; Wright *et al*., 2007; Wu and Tu, 2007; Deutsch *et al*., 2010), which is consistent with agency theory (Jensen and Meckling, 1976), other research shows that ESOs induce less risk taking (Larraza-Quintana *et al*., 2007; Sawers *et al*., 2011), which is in accordance with the behavioral agency model (BAM) developed by Wiseman and Gomez-Mejia (1998).

As Martin *et al*. (2013) highlight in their recent research, whereas agency theory focuses on the positive influence of prospective ESO wealth (i.e., the potential increase in intrinsic value), BAM focuses on the negative effect of current ESO wealth (i.e., intrinsic value) on risk taking. This research attempts to advance understanding by providing a more comprehensive explanation of the influence of ESOs, in particular the joint effect of current and prospective ESO wealth, on the top management team (TMT) risk-taking behavior, and therefore on firm risk taking. This joint effect is captured through the sensitivity of TMT wealth to changes in the firm's stock price, or TMT delta.

The unit of analysis in the present study is, thus, the entire TMT, which is the set of executives responsible for the strategic and organizational decisions that have a direct impact on firm performance. Although the CEO has overall responsibility for the conduct of the firm and performance outcomes, other TMT members also play an important role in meeting the firm's objectives, and exert a direct influence on complex corporate decisions such as investing in R&D (Alessandri and Pattit, 2014) and financial policy (Bertrand and Schoar, 2003; Chava and Purnanandam, 2010). Hence, it is necessary to look beyond the CEO and take into consideration the whole TMT in order to understand decision making at the top of the firm.

In relation to the TMT, it is relevant to consider an important aspect that the literature has not addressed in depth and may influence the relationship between ESOs granted to management and firm risk taking, which is the gender diversity in the TMT. Currently, together with top executive compensation, gender diversity is arguably one of the most debated features of boards of directors (Adams and Ferreira, 2009; Carter *et al.*, 2010; Lucas-Pérez *et al.*, 2014) and top management positions (Krishnan and Park, 2005; Dezso and Ross, 2012). This study takes TMT gender diversity into account because, although the evidence shows that male and female executives receive a similar amount of ESOs in their compensation packages (Munoz-Bullon, 2010; Vieito and Khan, 2012), there is a widespread view that women are both more risk averse and loss averse than men (Brooks and Zank, 2005; Croson and Gneezy, 2009; Charness and Gneezy, 2012), and thus the ESO effect on firm risk taking may change with different levels of female representation in the TMT.

The present study has two major goals. The first is to examine the relationship between current and prospective ESO wealth and firm risk taking by combining the arguments of agency theory and BAM. The second goal is to analyze how gender diversity in the TMT moderates the relationship between ESO grants and firm risk taking. Using panel data from six fiscal years (from June 2006 to May 2012) on TMTs of the S&P 1500 firms, our research design takes into account the fact that ESO incentives and firm risk taking are jointly determined. Furthermore, as Huang and Kisgen (2013) indicate, female executives are not randomly assigned to firms. Women's higher risk aversion and the level of firm risk may have an impact on the firm's decisions when hiring new TMT members. In addition, women may self-select themselves into firms that take less risk. Therefore, it is critical to address the endogenous nature of all these relationships in the empirical framework. In particular, we deal with endogeneity problems through a Generalized Method of Moments (GMM) estimation, a two-stage least squares (2SLS) instrumental variable estimation, and a propensity score procedure to form a matched sample of firms with gender diverse TMTs and non-gender diverse TMTs.

Applying different methods to consider potential endogeneity issues makes an important contribution to the literature from the point of view of empirical testing. In addition, in response to those studies which point out the limitations of the classical Black and Scholes (1973) model in the valuation of ESOs and their incentives (Devers *et al*., 2007; Goergen and Renneboog, 2011; Alvarez-Diez *et al*., 2014), we use the model developed by Cvitanic *et al*. (2008) which, through its completely analytical expression, adapts to the features of ESOs. From a more theoretical point of view, this research contributes to the literature in other ways. First, unlike previous studies that focused exclusively on CEOs (Larraza-Kintana *et al*., 2007; Devers *et al*., 2008; Martin *et al*., 2013), we use the TMT as our unit of analysis since, in addition to the CEO, other TMT members are also involved in formulating and carrying out firm risk-related policies that will affect performance outcomes (Chava and Purnanandam, 2010; Alessandri and Pattit, 2014). Second, as Eisenhardt (1989) and Boyd *et al*. (2012) suggest, we consider complementary theoretical perspectives to agency theory, particularly the framework of the BAM, in order to understand the complexity of incentive compensation and come to more meaningful findings. Finally, previous studies have analyzed the gender pay gap for top executives (Elkinawy and Stater, 2011; Kulich *et al*., 2011; Bugeja *et al*., 2012), but the literature does not address the question of whether TMT gender diversity has an effect on the risk taking motivated by ESOs.

The remainder of this chapter is structured as follows. Section 2 provides the theoretical framework and the research hypotheses. Section 3 describes the data, specifies the variables and presents the methodology used to test the hypotheses. Section 4 reports the empirical results. Finally, Section 5 provides conclusions to this study.

3.2. THEORETICAL FRAMEWORK AND HYPOTHESES

3.2.1. ESOs and firm risk taking

Two general paradigms can be considered in the area of ESOs and their incentive effects: agency theory (Jensen and Meckling, 1976) and BAM (Wiseman and Gomez-Mejia, 1998). Drawing on agency theory, executives are considered risk averse (Jensen and Meckling, 1976; Eisenhardt, 1989) and ESOs lead them to take more risk in search of increasing the firm's stock price, and therefore the value of their options, as the executives face no downside risk (Sanders, 2001). Thus, agency theory focuses on the role of the prospective ESO wealth in motivating risk taking (Martin *et al.*, 2013). However, the normative stream of agency theory (Harris and Raviv, 1979; Holmstrom, 1979; Shavell, 1979) considers that equity-based compensation creates excessive risk bearing for top executives, and thus they adopt conservative behavior by becoming even more risk averse. This stream of agency theory places emphasis on the importance of the risk bearing in relation to the ESOs' effect on risk taking behavior, which is also what the BAM considers.

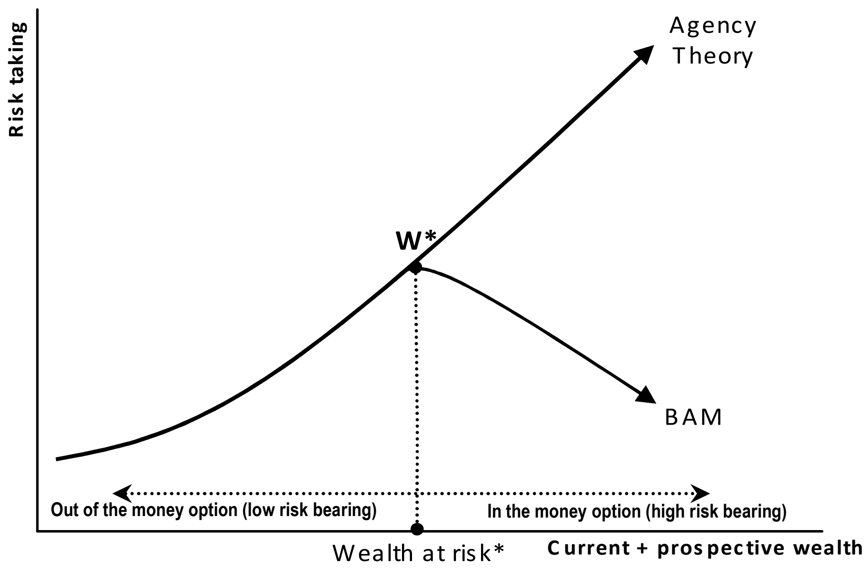
Risk bearing refers to the perceived risk that one is exposed to when there is a threat to executive wealth (Wiseman and Gomez-Mejia, 1998; Larraza-Kintana *et al.*, 2007). According to BAM, executives are loss averse, and therefore they try to protect their own current wealth from possible loss. The greater the exposure to risk, the less attractive risk taking is, since executives have more wealth at stake (Wiseman and Gomez-Mejia, 1998). Drawing on these arguments and focusing on ESOs, BAM supports the view that ESOs are part of the perceived current wealth of their holders, and therefore ESOs can lead to an increase in risk aversion among executives because ESOs may be associated with increasing risk bearing. Specifically, if the intrinsic value of the options is positive, loss averse executives are not willing to take risk because of the possibility of decreasing their perceived current wealth if the value drops. In contrast with this, if the intrinsic value is zero, ESOs do not create risk bearing, which will then not produce executive risk aversion (Wiseman and Gomez-Mejia, 1998; Larraza-Kintana *et al.*, 2007).

Some research has attempted to extend the original ideas of BAM and examine them empirically. Larraza-Kintana *et al*. (2007) and Sawers *et al*. (2011) support the predictions of BAM and find that as the intrinsic value of options increases, executive risk taking decreases. In contrast with this, Devers *et al*. (2008) show that the value of unexercisable stock options has a significant positive impact on risk taking. Recently, Martin *et al*. (2013) find support for both agency theory and BAM, by showing a positive (negative) relationship between prospective (current) ESO wealth and firm risk. This research indicates that the negative association suggested by BAM is positively moderated by the possibility of increasing the firm's stock price, that is, by the importance of prospective wealth supported by agency theory.

Following Martin *et al*. (2013), we take into account the possibility that both prospective ESO wealth and current ESO wealth influence the TMT risk-taking behavior, and consequently the level of firm risk. Extending this recent research, we suggest (see Figure 1) that in the situation in which the stock price is below the exercise price (out-of-the-money option) and starts to increase, the current wealth (or intrinsic value) is either zero or low and increases if the stock price continues to rise. However, in this situation the prospective ESO wealth has a higher relative weight with respect to the current ESO wealth, since TMT members will adopt risk-increasing behavior with the aim of increasing the firm's stock price, and therefore their wealth. In this circumstance, the agency theory view (Jensen and Meckling, 1976; Jensen and Murphy, 1990) dominates the impact on risk taking behavior and ESOs encourage executives to take more risk in search of increasing their wealth, because their losses are limited (Sanders, 2001). Following this argument, we predict that the TMT adopts risk-increasing behavior up to certain point, at which they consider that current wealth is too high and they are exposed to too much risk. That is, they perceive too much of their wealth is at risk, and this is the maximum wealth at risk that they are willing to bear (W*). From this point on, the current wealth has a higher relative weight with respect to the prospective wealth. This is due to the fact that if the ESO is in-the-money and the intrinsic value is high, TMT members consider that taking more risk may not lead to more increases in the firm's stock price. In this circumstance, the propositions of the BAM apply, and greater current wealth leads to greater risk bearing and executives adopt risk-reducing behavior to protect their perceived wealth (Wiseman and Gomez-Mejia, 1998; Larraza-Quintana *et al*., 2007, Sawers *et al*., 2011).

In summary, we suggest that the TMT risk-taking behavior, and therefore firm risk taking, is a combination of the agency and BAM perspectives and their emphasis on prospective and current wealth, respectively. This combination leads us to expect a concave relationship, as represented in Figure 1. That is to say, we expect that firm risk taking increases from low to moderate levels of current wealth (high prospective wealth) until top executives who make up the TMT perceive that too much of their wealth is at risk and, due to the greater risk bearing and the perception that there are fewer possibilities for increasing their wealth, their appetite for risk declines.

Figure 1. Effect of ESOs (current and prospective wealth) on risk taking



Hypothesis 1*: An inverted U-shaped relationship is expected between ESO wealth (current and prospective) and firm risk taking.*

3.2.2. The moderating role of TMT gender diversity

Gender constitutes and important measure of TMT diversity and, although prior research has produced mixed results, many previous studies show that gender diversity in top management positions has a positive impact on firm performance (Carter *et al*., 2003; Krishnan and Park, 2005; Adams and Ferreira, 2009; Dezso and Ross, 2012). Krishnan and Park (2005) point out that female representation at the top of the corporate hierarchy increases power sharing and minimizes social identity problems. More recently, Dezso and Ross (2012) indicate that, when the firm's strategy is focused on innovation, TMT gender diversity provides social and informational diversity benefits, enriches the behavior exhibited by executives and improves the team's task performance.

It is clear that gender diversity is arguably one of the most debated issues in organization live but, despite the slight increase in the number of women at the top of large firms, the presence of female executives is still limited (Daily *et al*., 1999; Helfat *et al*., 2006; Dezso and Ross, 2012; Mohan, 2014). Although the behavior of top executives differs according to gender with regard to several aspects, such as caution, aggressiveness and leadership (Johnson and Powell, 1994), one possible explanation of the low number of women in top corporate positions is the widespread view of higher female risk aversion (Johnson and Powell, 1994; Mohan, 2014). In this regard, considering the financial and labor markets as a whole, Shubert *et al*. (1999) find statistical discrimination against women due to the stereotype that they are more risk averse than men. Drawing upon theoretical perspectives of discrimination, Mateos *et al*. (2011) find that there are fewer women in upper-level corporate positions in those firms with more risk, that is, more variability in their performance. These researchers remark that if females are less willing to take greater risks, firms will exclude women from those positions that are more related to risk taking. Similar results are found by Mateos *et al*. (2012) in the banking sector.

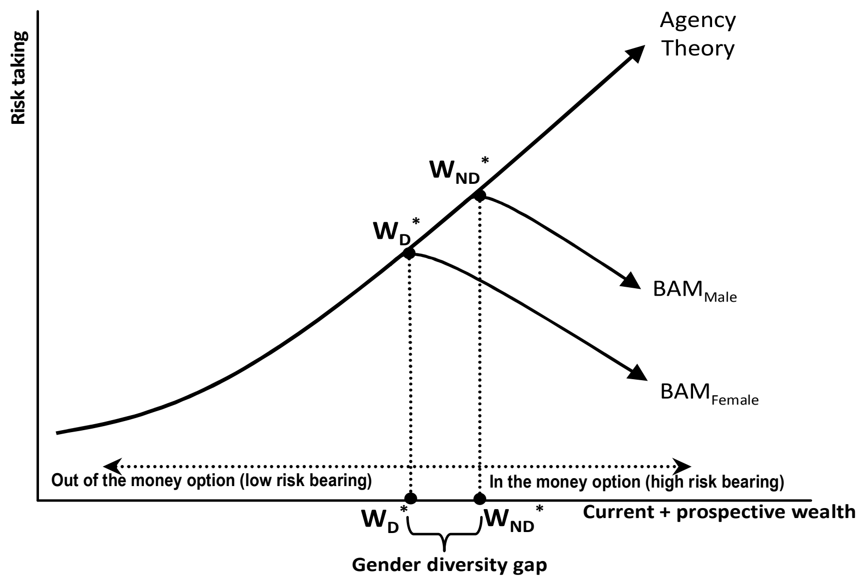
Considerable empirical evidence supports the idea that women are more risk averse than men in such areas as financial and investment decisions (Jianokoplos and Bernasek, 1998; Barber and Odean, 2001; Charness and Gneezy, 2012; Halko *et al*., 2012) and retirement asset investments (Bernasek and Shwiff, 2001; Arano *et al*., 2010). Other experiment-based research also supports the common assertion of that men take more risks than women (Vandergrift and Brown, 2005; Ertac and Gurdal, 2012) and, due to their lower risk taking and confidence, women are also less willing to enter to a competition than men (Niederle and Vesterlund, 2007; Kamas and Preston, 2012). These general gender-based differences regarding the attitude toward risk also extend to areas of business and management. Previous studies have shown the greater risk aversion of female entrepreneurs (Collerette and Aubry, 1987; Olson and Currie, 1992) and, in management positions, the evidence also shows the preference of female executives to take less risk than their male counterparts (Muldrow and Bayton, 1979; Martin *et al*., 2009; Elsaid and Ursel, 2011; Khan and Vieito, 2013). Croson and Gneezy (2009) indicate the possible factors that may lead men and women to differ in their responses to risk, which are gender differences in emotional reactions to risky situations, differences in levels of confidence and different views of uncertain situations as either a challenge or a threat.

In addition to gender differences in relation to risk aversion, several experimental studies also support the view that women are more loss averse than men (Schmidt and Traub, 2002; Brooks and Zank, 2005), that is, women show a greater preference for avoiding losses rather than making gains in comparison with their male counterparts. Integrating the assumptions of executive risk aversion of agency theory (Jensen and Meckling, 1976) and executive loss aversion of BAM (Wiseman and Gomez-Mejia, 1998) with gender-based differences, Schmidt and Traub (2002: pp. 245-246) conclude that “women have a higher degree of risk aversion than men at least partly because they are more loss averse”.

Not only do women take fewer risks than men in the individual decision-making task, but women also show higher risk aversion when they have to make decisions on behalf of a group (Ertac and Gurdal, 2012). All these arguments lead us to say that the higher female risk and loss aversion will have an influence on the TMT decision making and the TMT risk-taking behavior, and therefore on firm risk taking. Consequently, it is important to examine the effect of TMT gender diversity on the relationship between ESOs and firm risk taking. In particular, it is likely that those TMTs with female executives are less willing to accept exposure to certain levels of risk and the presence of women in the TMT influences the perceived wealth at risk created by ESOs. TMTs with female executives will perceive a certain level of current and prospective wealth as more wealth at risk, or more risk bearing, compared with the perceptions of those TMTs composed exclusively of men. Then, the inverted U-shaped relationship suggested in the previous section may differ if we take into account the effect of female representation in the TMT (see Figure 2). In particular, we expect that after the risk-increasing behavior supported by agency theory, the point of wealth at risk at which the TMT adopts risk-reducing behavior is lower for gender diverse TMTs than for non-gender diverse TMTs. In other words, while those TMTs in which there is female representation may exhibit more conservative behavior by taking fewer risks, TMTs in which there are only male executives will be associated with more risk taking.

As shown in Figure 2, we suggest that there is a gender diversity gap in which non-gender diverse TMTs continue with the risk-increasing behavior supported by agency theory, while gender diverse TMTs start risk-reducing behavior as predicted by the BAM view. Thus, after the risk-increasing behavior associated with low and moderate levels of current ESO wealth (high prospective wealth), we expect that those TMTs in which there is female representation adopt risk-reducing behavior when the relative weight of current wealth with respect to prospective wealth is lower (W_D*) compared to that of non-gender diverse TMTs (W_{ND}*).

Figure 2. Effect of TMT gender diversity on the relationship between ESOs and risk taking



***Hypothesis 2**: The point of wealth at risk at which the risk-increasing behavior turns into risk-reducing behavior is lower for gender diverse TMTs.*

3.3. METHODS

3.3.1. Data and sample

We focus on executives at the top management level in firms included in Standard and Poor's (S&P) ExecuComp database. ExecuComp contains compensation data about the five highest-paid executives for S&P listed firms (covering firms in the S&P 500, S&P Midcap 400, and S&P SmallCap 600). The literature reports that compensation level is a good proxy for the position within the corporate hierarchy (Finkelstein and Hambrick, 1996). We take the executives included in ExecuComp (the CEO and four other non-CEO executives) to be a firm's TMT, which is consistent with the definition of TMT used in prior literature

(Fredrickson *et al*., 2012). We also use the Compustat database as a source of accounting data and stock return information. The final sample is an unbalanced panel of 1,123 publicly traded firms in the US (firms in the S&P500, S&P Midcap 400 and S&P Smallcap 600), from which we take 4,790 TMT-year observations covering six fiscal years, from June 2006 to May 2012.

As both Carpenter and Sanders (2002) and Dezso and Ross (2012) indicate, considering the CEO and the four highest paid non-CEO executives as the firm's TMT our study is consistent with the upper echelons literature that reports the inner circle of TMTs to number between three and seven people. Moreover, not only the CEO, but also other TMT members influence risk-related corporate policies (Chava and Purnanandam, 2010; Alesasandri and Pattit, 2014) and hold prestigious positions within the firm, having authority in certain areas. For example, the chief operating officer (COO) has broad oversight over the firm as a whole, in contrast with heads of large divisions that bear responsibility for a narrow set of the firm's activities (Aggarwal and Samwick, 2003), while the chief financial officer (CFO) exerts a direct influence on the firm's financial policy (Bertrand and Schoar, 2003; Chava and Purnanandam, 2010). All of these arguments justify looking beyond the CEO and considering the entire TMT as the unit of analysis, as in the present study.

3.3.2. Variables

Firm risk taking (*RISK*). We use firm risk taking as the dependent variable in our models and, as in other studies (Jin, 2002; Armstrong and Vashishtha, 2012; Vieito and Khan, 2012), it is measured as the standard deviation of monthly firm stock returns over a period of five years ($RISK_{5\ years}$), that is, the 60 monthly observations prior to the end of each fiscal year. Alford and Boatsman (1995) argue that monthly stock returns over a time period of five years provides the most accurate volatility estimator when using historical data. In addition, as a robustness check, we extend our analysis by measuring firm risk taking as the standard deviation of daily stock returns over the last 90 trading days prior to each fiscal year-end ($RISK_{90\ days}$).

Current and prospective ESO wealth (*DELTA_TMT*). Unlike Martin *et al*. (2013), who use two different variables in order to capture the effect of current and prospective wealth, we consider a single measure which combines both forms of ESO wealth. This measure is the sensitivity of executive wealth to stock price, or delta. Delta measures the option value, which is the sum of the current wealth (intrinsic value) and prospective wealth (temporal value), in a continuous way. *DELTA_TMT* is measured as the rate of change of the TMT's equity portfolio value[1] for a 1% change in the firm's stock price, which is consistent with previous studies (Core and Guay, 1999; Low, 2009; Dong *et al*., 2010)

Other ESO incentives (*VEGA_TMT*). We also consider in our models the stock option incentive to increase stock volatility, or vega, since the evidence shows that vega is positively related to risk taking (Guay, 1999; Coles *et al*., 2006; Armstrong and Vashishtha, 2012). Accordingly, *VEGA_TMT* is defined as the rate of change of the TMT's option value[2] for a 1% change in the stock return volatility. Most previous empirical studies have used the Black-Scholes (1973) model (BS) to estimate the value of ESOs and their incentive effects, even though it does not consider the main features of ESOs, and this may lead to erroneous results from the point of view of asset valuation. Thus, we estimate both deltas and vegas using the Cvitanic-Wiener-Zapatero (2008) model (CWZ) since, through its analytical formula, it takes the main characteristics of ESOs into account. Moreover, as in prior research (Knopf *et al*., 2002; Low, 2009; Coles *et al*., 2006; Brockman *et al*., 2010), we apply the method developed by Core and Guay (2002) to approximate

[1] Following previous studies (Brockman *et al*., 2010; Dong *et al*., 2010; Armstrong and Vashishtha, 2012), we obtain delta values by taking into account not only the TMT's option portfolio, but also the TMT's stock portfolio.

[2] With respect to vega, we only consider the TMT's option portfolio since Guay (1999) shows that the vega of a stock portfolio is extremely small compared to that of an option portfolio. Thus, previous studies have focused on calculating vega by taking into consideration only the stock options that executives have in their compensation packages (Rajgopal and Shevlin, 2002; Coles *et al*., 2006; Brockman *et al*., 2010).

deltas and vegas for previously granted options. In order to compare results and see potential limitations, we also include the BS model[3] in our analysis.

TMT gender diversity (*GENDIV*). In order to test Hypothesis 2, we measure the TMT gender diversity as the percentage of women in the firm's TMT (Krishnan and Pack, 2005; Dezso and Ross, 2012).

Firm and CEO characteristics. Consistent with previous studies (Coles *et al*., 2006; Brockman *et al*., 2010), we control for the influence of the following variables related to firm characteristics: research and development expenditure (*RD*), measured as research and development expenditure scaled by total assets; net capital expenditure (*CAP*), measured as capital expenditure less sales of property, plant and equipment divided by total assets; diversification (*DIV*), measured as the logarithm of the number of the firm's operating segments; leverage (*LEV*), measured as total book debt divided by the book value of assets; firm size (*SIZE*), measured as the logarithm of total assets. In addition to the delta and vega of the CEO (*DELTA_CEO* and *VEGA_CEO*, respectively), we include several variables in the models in order to control for other CEO characteristics: *GENDER* captures the CEO gender through a dummy variable that is equal to 1 if the CEO is a woman (Devers *et al*., 2008); *CASHCOMP* is the CEO cash compensation, measured as the sum of the CEO's salary plus bonus (Coles *et al*., 2006); and *TENURE* is the CEO tenure measured as the logarithm of the number of years that the CEO has held that position (Armstrong and Vashishtha, 2012).

3.3.3. Analysis

We test our hypotheses studying the dynamics of cross-sectional populations through a panel data methodology. This methodology gives more

[3] Under the BS and CWZ models, the expressions of delta and vega contain the following parameters: E = exercise price (ExecuComp), T = time to maturity (ExecuComp), S = the stock price at the end of each fiscal year (ExecuComp), σ = the annualized volatility (standard deviation of monthly returns over the last five years), r = risk-free interest rate (U.S. Treasury bond yield at 10 year-constant maturity), q = dividend yield (Compustat). Regarding the specific parameters of the CWZ model, we follow Alvarez-Diez *et al*. (2014).

information and variability, less collinearity among variables and more efficiency compared to other methods (Baltagi, 2001), and therefore both the econometric specifications and the parameter estimation are improved. Moreover, we must take into account the fact that firms and executives are heterogeneous. Consequently, features such as prestige, personal skills and experience that are difficult to measure or to obtain may have an influence on firm risk and may bias the model's results if we ignore them. In order to avoid biased results, the panel includes an individual effect, η_i, to control for unobservable heterogeneity. Thus, the error term is $\varepsilon_{it} = \eta_i + \upsilon_{it}$, where υ_{it} is a random disturbance. The time effect is also controlled by year dummies, ψ_t. The model represented in Equation (1) is used to test Hypothesis 1 and we regress the level of firm risk against delta and its square to test the concavity of the relationship.

$$\begin{aligned} RISK_{it} = {} & \beta_1 \cdot DELTA\_TMT_{it} + \beta_2 \cdot DELTA\_TMT_{it}^2 + \beta_3 \cdot VEGA\_TMT_{it} + \\ & + \sum \beta \cdot CEO\,control_{it} + \sum \beta \cdot FIRM\,control_{it} + \psi_t + \eta_{it} + \upsilon_{it} \end{aligned} \tag{1}$$

We expect ESO incentives to influence firm risk taking but, as the literature points out, it is quite likely that firm risk also affects ESO incentives (Coles *et al.*, 2006; Armstrong and Vashishtha, 2012; Alvarez-Diez *et al.*, 2014). The firm, or particularly the board of directors, will take into consideration the risk profile of the firm and the potential effect on risk behavior of ESO incentives when designing compensation packages. Consequently, ESO incentives and firm risk are jointly determined. Moreover, Hypothesis 2 refers to the moderating role of TMT gender diversity on the relationship between ESOs and firm risk taking, which implies that there are other endogenous relationships that this study should consider. These other endogeneity issues arise because female executives are not randomly assigned to firms. On the one hand, firm risk taking may have an influence on the firm's decision about hiring a male or a female executive. It is possible that due to their higher risk aversion, firms exclude women from those positions that are more concerned with risk taking (Shubert *et al.*, 1999; Mateos *et al.*, 2011, 2012). Those firms which aim to carry out riskier projects may opt for hiring men rather than women for the TMT, since female executives are seen as being less willing to make the risky decisions that may be necessary for the firm's success. Following the same argument, those firms with high levels of risk that are looking to reduce their exposure to risk may prefer to appoint female executives (Martin *et al*., 2009). On the other hand, higher risk aversion may lead women to self-select to firms which take less risk or self-select themselves only for a particular kind of industry. One indicator of these endogeneity issues is that female executives are usually concentrated in specific industries, such as manufacturing, retail trades and utilities (Mohan, 2014).

The main estimation method used in this study to solve endogeneity problems is the instrumental variable method based on the Generalized Method of Moments (GMM) proposed by Arellano and Bond (1991). In addition, in order to mitigate potential endogeneity problems related to risk taking and female representation in the TMT and seeking robustness in our GMM findings, we conduct two additional analyses. First, we apply a two-stage least squares (2SLS) instrumental variable approach in which the exogenous instrument is based on the score that Sugarman and Straus (1988) assign to each of the 50 US states for its gender equality status. Finally, we employ a propensity score procedure (Rosenbaum and Rubin, 1983) in order to identify a control sample of firms that have a non-gender diverse TMT but have similar characteristics to the firms with gender diverse TMTs.

In the GMM instrumental variable approach, we use the first-differenced GMM estimator developed by Arellano and Bond (1991) which, in addition to controlling for individual effects, solves the endogeneity problem. Endogenous variables in first-differences are instrumented with several lags of their own levels. The Hansen (1982) test statistics for overidentifying restriction is used to test the validity of the instruments. Although it is consistent for large panels, we do not apply the basic first-differenced two-stage least squares for panel data models of Anderson and Hsiao (1981) because the GMM technique exploits more moment conditions and therefore is asymptotically efficient. Moreover, when the regressors are endogenously determined along with the dependent variable, parameter estimates from ordinary least squares (OLS), within groups or first-differenced OLS estimators are inconsistent, and the Hausman test is not valid. Therefore, we apply the GMM technique to estimate models proposed in Equation (1) and Equation (2). Equation (2) includes the main effect and the multiplier effect of the variable that captures the gender diversity in the TMT in order to test Hypothesis 2.

$$\begin{aligned} RISK_{it} &= (\beta_1 + \beta_1^* \cdot GENDIV_{it})DELTA\_TMT_{it} + \\ &+ (\beta_2 + \beta_2^* \cdot GENDIV_{it})DELTA\_TMT_{it}^2 + \\ &+ \beta_3 \cdot GENDIV_{it} + \beta_4 \cdot VEGA\_TMT_{it} + \\ &+ \sum \beta \cdot CEO\,control_{it} + \sum \beta \cdot FIRM\,control_{it} + \\ &+ \psi_t + \eta_{it} + \upsilon_{it} \end{aligned} \tag{2}$$

As far as the exogenous instrumental variable approach is concerned, the instrument that we use for a TMT including female executives is based on the study of Sugarman and Straus (1988). Sugarman and Straus (1988) construct indicators of gender equality for each of the 50 US states by taking into account the economic, political, and legal spheres. They assign each of the states a score for its gender equality status. The score of the overall gender equality index ranges from 19.2 (Mississippi) to 59.9 (Oregon). The state of Florida has the median score of 42.3, which means that women have achieved less than half of what is needed for gender equality. This instrumental variable approach is used in the recent study of Huang and Kisgen (2013). Following these researchers, we consider that the more friendly a state is to women's equality (i.e., the higher the score assigned to a state), the more likely a firm headquartered in that state is to have at least one female executive in its TMT. Said another way, higher values mean more favourable gender equality in the state, and therefore a higher probability of the firms headquartered in that state having women in the TMT. Therefore, the instrument that we use to test Hypothesis 2 is the state's gender equality value for each firm according to the firm's location (*GENEQUALITY*).

While the gender equality assigned to a state is correlated with the presence of women in the firm's TMT headquartered in that state, this instrumental variable does not have any influence on the level of firm risk. Consequently, the instrument is valid. We estimate our model using a 2SLS regression analysis. In the first-stage regressions, we estimate the predicted values of the endogenous variables (i.e., *GENDIV*, *DELTA_TMT·GENDIV*, and $DELTA\_TMT^2 \cdot GENDIV$) by regressing each of them on the instrumental variable (i.e., *GENEQUALITY, DELTA_TMT·GENEQUALITY*, and $DELTA\_TMT^2 \cdot GENEQUALITY$) and the other exogenous controls. In the second-stage regression (Equation 3), we use the predicted values of the endogenous variables obtained through the first-stage regressions ($Instrumented\,GENDIV$, $Instrumented\,DELTA\_TMT \cdot GENDIV$ and $Instrumented\,DELTA\_TMT^2 \cdot GENDIV$) to estimate the risk-profile equation.

$$\begin{aligned} RISK_{it} &= \beta_1 \cdot DELTA\_TMT_{it} + \beta_1^* \cdot Instrumented\,DELTA\_TMT_{it} \cdot GENDIV_{it} + \\ &+ \beta_2 \cdot DELTA\_TMT_{it}^2 + \beta_2^* \cdot Instrumented\,DELTA\_TMT_{it}^2 \cdot GENDIV_{it} + \\ &+ \beta_3 \cdot Instrumented\,GENDIV_{it} + \beta_4 \cdot VEGA\_TMT_{it} + \\ &+ \sum \beta \cdot CEO\,control_{it} + \sum \beta \cdot FIRM\,control_{it} + \\ &+ \psi_t + \eta_{it} + \upsilon_{it} \end{aligned} \tag{3}$$

Following previous recent studies (Huang and Kisgen, 2013; Faccio *et al.*, 2014), we conduct our last robustness analysis on samples matched on the basis of propensity scores (Rosenbaum and Rubin, 1983). The aim is to find a control sample of firms that have a non-gender diverse TMT but have similar characteristics to those firms with gender diverse TMTs. The first step of this procedure is to calculate the probability (propensity score) that a firm with given characteristics has a gender diverse TMT. This step corresponds to a probit model (Equation 4), where the dependent variable is a TMT gender diversity dummy variable (*DGENDIV*) and the independent variables are the following: research and development expenditure, net capital expenditure, diversification, leverage, firm size, CEO cash compensation, CEO tenure, and year dummies.

$$DGENDIV_{it} = \sum \beta \cdot FIRM\ control_{it} + \sum \beta \cdot CEO\, control_{it} + \psi_t + \eta_{it} + \upsilon_{it} \qquad (4)$$

We use the propensity scores obtained from this regression to ensure that the firms that make up the control sample have similar characteristics to the firms with gender diverse TMTs. To do that, the maximum difference of the propensity score of the firm with gender diverse TMT and that of non-gender diverse TMT cannot exceed 0.1% (absolute value) (Faccio *et al*., 2014). In this way, we pair gender diverse TMT-year observations with non-gender diverse TMT-year observations with statistically the same research and development expenditure, capital expenditure, and other characteristics mentioned above. Later, using the matched sample we conduct regressions of the decision variables of interest using the gender diverse dummy (*DGENDIV*) (Equation 5).

$$\begin{aligned} RISK_{it} &= (\beta_1 + \beta_1^* \cdot DGENDIV_{it})DELTA\_TMT_{it} + \\ &+ (\beta_2 + \beta_2^* \cdot DGENDIV_{it})DELTA\_TMT_{it}^2 + \\ &+ \beta_3 \cdot DGENDIV_{it} + \beta_4 \cdot VEGA\_TMT_{it} + \\ &+ \sum \beta \cdot CEO\, incentives_{it} + \psi_t + \eta_{it} + \upsilon_{it} \end{aligned} \qquad (5)$$

3.4. RESULTS

Table 1 provides descriptive statistics of the variables used in this study. In the case of the deltas and vegas calculated through the CWZ model, we provide three values that correspond to three different levels of the barrier used to capture the early exercise behavior. Following Alvarez-Diez *et al*. (2014), L_1, L_2 and L_3 refer to 1.5, 2 and 2.5 times the exercise price, respectively.

Panel A of Table 1 shows summary statistic grouping variables according to TMT characteristics and firm characteristics. Regarding TMT characteristics, the average TMT wealth under the CWZ model increases by $1,803,550, $1,730,940 and $1,705,990 (for each level of the barrier) for a 1% increase in the firm’s stock price. However, the BS model shows a larger change in the TMT's wealth for a 1% change in the stock price compared to those of the CWZ model, particularly a mean value of $2,028,240, which is consistent with prior research that highlights the low variability and overvaluation that BS model causes when applied to ESOs (Goergen and Renneboog, 2011; Alvarez-Diez *et al*., 2014). With respect to TMT vega values, we find that a 0.01 increase in the stock return volatility results in an average increase in the TMT's wealth of $298,560, $362,410 and $365.100 for the cases of the CWZ model and $447,790 under the BS model. As far as TMT gender diversity is concerned, the average level of gender diversity in our sample is extremely low (6%), and this variable is strongly asymmetric since more than 50% of the firms do not have any women in their TMT, which means that the presence of women in top management level of large firms is still low. Regarding firm characteristics, Panel A shows that the average level of firm risk is about 37%, the average research and development expenditures is 2.24% and the average net capital expenditures and leverage are 4.20% and 21.34%, respectively.

With respect to CEOs, Panel B of Table 1 shows that CEOs have larger portfolio equity incentives than the rest of the TMT (shown in Panel C). The mean delta values are around $1,150,000 and $1,128,000 for the case of the CWZ and BS models, respectively, which is in line with the values reported by Dong *et al*. (2010). If we compare these mean values with previous empirical research (Guay, 1999; Knopf *et al*., 2002; Coles *et al*., 2006), our numbers are larger because we analyze a more recent time period (from June 2006 to May 2012) and, as Murphy (2013) shows, the levels of total compensation and equity-based compensation in US firms are still high and have increased since 2009. A 0.01 increase in the stock return volatility results in an average increase in CEO wealth of $149,200, $180,440 and $182,250 under the CWZ model and $219,240 under the BS model, which is consistent with previous studies (Knopf *et al*., 2002; Hayes *et al*., 2012). Separating the sample of CEOs by gender, we can observe that male CEOs have larger mean delta and vega values compared with their female counterparts. In addition, male CEOs receive on average more cash compensation and have been occupying their position in the corporate hierarchy for longer.

Table 1. Descriptive Statistics

Panel A: Full sample

	Mean	SD	10th percentile	Median	90th percentile
TMT characteristics (including the CEO)					
DELTA_CWZ_L1[a]	1803.55	11203.26	123.73	590.41	3136.59
DELTA_CWZ_L2[a]	1730.94	11098.10	122.42	560.38	2905.88
DELTA_CWZ_L3[a]	1705.99	10933.10	123.39	552.17	2791.88
DELTA_BS[a]	2028.24	11329.09	166.78	748.44	3603.50
VEGA_CWZ_L1[a]	298.56	598.41	15.99	116.87	719.78
VEGA_CWZ_L2[a]	362.41	735.73	19.61	142.01	861.19
VEGA_CWZ_L3[a]	365.10	710.69	18.04	139.97	872.08
VEGA_BS[a]	447.79	734.89	40.27	224.42	1057.60
GENDIV	0.06	0.11	0.00	0.00	0.20
Firm characteristics					
$RISK_{5\ years}$[c]	36.64	14.14	21.23	34.21	55.02
$RISK_{90\ days}$[c]	37.98	20.88	18.88	33.13	61.63
RD[c]	2.24	4.50	0.00	0.00	8.60
CAP[c]	4.20	4.87	0.00	2.79	9.59
LEV[c]	21.34	17.56	0.00	19.52	44.83
DIV[d]	0.95	0.70	0.00	1.10	1.79
SIZE[d]	7.76	1.63	5.76	7.62	9.97

Panel B: CEO characteristics by gender

	All CEOs	Male CEOs	Female CEOs	Mann-Whitney U test
DELTA_CWZ_L1[a]	1171.48	1196.78	299.11	4.305***
DELTA_CWZ_L2[a]	1132.83	1157.17	293.83	4.198***
DELTA_CWZ_L3[a]	1117.70	1141.40	300.48	4.047***
DELTA_BS[a]	1282.23	1307.54	409.30	3.944***
VEGA_CWZ_L1[a]	149.20	150.46	106.06	2.526**
VEGA_CWZ_L2[a]	180.44	181.88	131.03	2.311**
VEGA_CWZ_L3[a]	182.25	183.14	151.53	1.617
VEGA_BS[a]	219.24	219.98	193.77	1.296
CASHCOMP[a]	1089.70	1092.77	983.91	-0.458
TENURE[b]	8.21	8.31	5.09	5.702***

Panel C: TMT characteristics (without the CEO) by gender diversity

	All TMTs	Non-gender diverse TMTs	TMTs with gender diverse < mean	TMTs with gender diverse > mean	Kruskal–Wallis test
DELTA_CWZ_L1[a]	632.08	657.57	601.95	542.57	39.586***
DELTA_CWZ_L2[a]	598.10	618.12	565.11	517.84	38.690***
DELTA_CWZ_L3[a]	588.29	608.21	550.44	517.63	36.875***
DELTA_BS[a]	746.02	761.53	746.35	639.29	39.383***
VEGA_CWZ_L1[a]	149.35	144.76	188.88	110.87	47.152***
VEGA_CWZ_L2[a]	181.97	174.19	236.29	141.65	44.987***
VEGA_CWZ_L3[a]	182.85	174.47	236.24	149.24	40.215***
VEGA_BS[a]	228.55	220.04	286.08	187.34	42.157***

Panel A reports descriptive statistics grouping variables according to *TMT characteristics* and *Firm characteristics*. Panel B reports mean values of CEO characteristics distributed by the CEO gender. Panel C presents mean values of TMT characteristics (without the CEO) distributed by gender diversity. See variable definitions in Section 3.3.2. Mann-Whitney U is the non-parametric test of differences in the average between two groups. Kruskal–Wallis test is the extension of the Mann–Whitney U test to 3 or more groups. CWZ: Cvitanic *et al.* (2008) model. BS: Black and Scholes (1973) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. [a]: $000s. [b]: years. [c]: percentage. [d]: logarithm. SD: standard deviation.

** and *** Significant at 5% and 1%, respectively.

Panel C of Table 1 shows TMT characteristics (without the CEO) distributed by gender diversity, where the third column refers to those TMTs with only male executives and the fourth and fifth column refer to TMTs with gender diversity below or above the average gender diversity value, respectively. In line with the differences shown in Panel B, as the female representation in the TMT increases, delta and vega values decrease. Most of the differences shown in Panel B between male and female CEOs and in Panel C between non-gender diverse and gender diverse TMTs are statistically significant, and are evidence of the higher risk aversion of females.

In Tables 2 and 3, we present the GMM results of the model used to test Hypothesis 1. The difference between Table 2 and Table 3 is the measure of firm risk. While in Table 2 we use as the dependent variable the standard deviation of monthly stock returns for the 60 months prior to each fiscal year-end, Table 3 shows the GMM results using as measure of firm risk the daily stock returns over the last 90 trading days prior to each fiscal year-end. Note that the last four columns of both tables correspond to deltas and vegas of the TMT omitting the CEO, in order to examine if the definition of TMT used has an influence on the results; but our main interest is on the whole TMT.

According to Hypothesis 1, the TMT exhibits risk-increasing behavior up to a certain level of wealth, which is the maximum wealth at risk that the TMT is willing to bear. From this point on, the TMT adopts risk-decreasing behavior in order to protect the perceived current wealth and because of the perception of fewer possibilities for increasing the wealth. Consistent with this prediction, the variable that measures current and prospective wealth, $DELTA\_TMT_{it}$, should be significantly and directly related to firm risk taking, while the squared value of this variable should be significantly but inversely related to risk taking. Taking the first derivative of the model represented in Equation (1) with respect to $DELTA\_TMT_{it}$ and making it equal to zero, we obtain the breakpoint or point of inflection of the concave relationship, which is $DELTA\_TMT_{it} = -\beta_1 / 2\beta_2$. In order to support Hypothesis 1, this point should be a maximum and it happens when the coefficient of the squared value of $DELTA\_TMT_{it}$ (β_2) is negative; in this way, the inverted U-shaped relationship is confirmed.

Focusing on the results obtained in Tables 2 and 3, we find the expected signs of the coefficient of the variable $DELTA\_TMT_{it}$ and its square for all the models included in these two tables (with the exception of deltas and vegas calculated using the BS model). That is, while β_1 is positive and significant, β_2 is negative and significant for each of the levels of the barrier considered using the CWZ model. Considering the whole TMT and the three levels of the barrier using the CWZ model, on average, the value of the maximum wealth at risk at which the risk-increasing behavior changes to risk-decreasing behavior (W^* in Figure 1) is approximately $120,000 if we measure firm risk using the 60-month period and $130,000 in the case of the 90-day period. These findings support the concave relationship between the sum of current and prospective ESO wealth captured through delta values and the level of firm risk, as Hypothesis 1 predicts. In other words, the TMT adopts risk-increasing behavior at low to moderate values of delta, but TMT members show a decreasing preference for risk as delta further increases to substantial values. The last four columns of Tables 3 and 4 indicate the same pattern when we separate the CEO from the TMT. Both the CEO as an individual and the rest of TMT members as a group show the inverted U-shaped relationship between ESO wealth and firm risk taking. As expected, the Black-Scholes (1973) model does not offer stable findings and does not identify the concave relationship predicted by the combination of agency theory and BAM. This is due to the fact that, unlike the CWZ model, the BS model does not take into account the main features of ESOs. Consequently, the great variety of ESOs analyzed in this study (current granted ESOs, previously granted unexercisable ESOs, previously granted exercisable ESOs) is not captured in the BS estimations.

Table 2. GMM Estimation of the influence of TMT delta on firm risk (*$RISK_{5\ years}$*)

	Whole TMT				TMT without the CEO			
	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS
DELTA_TMT	9.283***	7.924***	5.301**	-4.155	7.168***	5.526***	4.768***	0.938
	(2.001)	(2.270)	(2.306)	(2.734)	(1.251)	(1.339)	(1.338)	(1.589)
DELTA_TMT^2	-0.876***	-0.841***	-0.674***	-0.018	-0.629***	-0.562***	-0.522***	-0.234*
	(0.147)	(0.1668)	(0.170)	(0.193)	(0.101)	(0.108)	(0.109)	(0.122)
VEGA_TMT	2.861***	1.200***	1.699***	5.445***	1.959***	0.569**	0.796***	1.808***
	(0.361)	(0.235)	(0.145)	(0.377)	(0.339)	(0.273)	(0.217)	(0.421)
DELTA_CEO					3.987***	3.804***	2.461*	-1.458
					(1.194)	(1.264)	(1.273)	(1.561)
DELTA_CEO^2					-0.546***	-0.545***	-0.451***	-0.132
					(0.099)	(0.106)	(0.107)	(0.124)
VEGA_CEO					1.279***	0.491**	0.949***	2.693***
					(0.283)	(0.227)	(0.192)	(0.389)
GENDER	4.082	9.575	1.772	-2.184	4.985	9.083	-0.549	-2.739
	(5.872)	(6.285)	(6.231)	(0.727)	(5.692)	(5.874)	(5.858)	(5.907)
CASHCOMP	-0.001***	-0.001***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000**	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
TENURE	0.257	-0.498*	-0.510*	-0.480	1.271***	0.320	0.205	0.166
	(0.287)	(0.301)	(0.296)	(0.295)	(0.325)	(0.338)	(0.334)	(0.341)
RD	2.905***	3.273***	3.012***	3.027***	2.808***	3.009***	2.795***	2.842***
	(0.273)	(0.289)	(0.285)	(0.279)	(0.260)	(0.270)	(0.270)	(0.265)
LEV	-0.134***	-0.123***	-0.157***	-0.163***	-0.120***	-0.115***	-0.152***	-0.164***
	(0.033)	(0.035)	(0.035)	(0.035)	(0.032)	(0.033)	(0.033)	(0.033)
CAP	-0.247***	-0.192***	-0.201***	-0.142**	-0.264***	-0.198***	-0.198***	-0.169***
	(0.054)	(0.057)	(0.056)	(0.056)	(0.053)	(0.055)	(0.054)	(0.054)
DIV	-4.214***	-3.300***	-3.620***	-2.391*	-3.204***	-2.393**	-2.630**	-1.724
	(1.192)	(1.264)	(1.246)	(1.246)	(1.114)	(1.167)	(1.165)	(1.153)
SIZE	5.089***	7.058***	5.494***	4.664***	3.671***	5.794***	4.449***	3.696***
	(0.886)	(0.912)	(0.914)	(0.919)	(0.857)	(0.857)	(0.861)	(0.873)

Firm risk is measured as standard deviation of monthly firm stock returns over five years (*$RISK_{5\ years}$*). See independent variable definitions in Section 3.3.2. CWZ: Cvitanic *et al.* (2008) model. BS: Black and Scholes (1973) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses. *, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 3. GMM Estimation of the influence of TMT delta on firm risk (*$RISK_{90\ days}$*)

	Whole TMT				TMT without the CEO			
	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS
DELTA_TMT	1.428**	1.214*	5.530**	-46.093***	3.758**	2.692*	0.132*	-15.748
	(0.699)	(0.709)	(2.759)	(8.844)	(1.802)	(1.391)	(0.080)	(13.864)
$DELTA\_TMT^2$	-0.847**	-0.974**	-0.464**	2.338***	-0.575*	-0.529**	-0.369**	0.818*
	(0.404)	(0.462)	(0.225)	(0.626)	(0.339)	(0.213)	(0.170)	(0.472)
VEGA_TMT	1.434	4.824***	4.842***	21.951***	2.303**	0.753	1.218*	5.562***
	(1.212)	(0.743)	(0.467)	(1.219)	(1.142)	(0.881)	(0.712)	(1.388)
DELTA_CEO					6.905*	7.991**	4.795**	-16.901***
					(4.023)	(4.08)	(2.139)	(5.136)
$DELTA\_CEO^2$					-1.323***	-1.408***	-1.074***	0.757
					(0.335)	(0.341)	(0.352)	(0.546)
VEGA_CEO					3.852***	4.137***	3.827***	14.509***
					(0.952)	(0.732)	(0.628)	(1.282)
GENDER	24.981	37.506	36.748	28.140	24.806	24.709	24.586	12.520
	(19.714)	(42.012)	(26.655)	(20.207)	(19.172)	(18.966)	(19.177)	(19.465)
CASHCOMP	-0.001	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
TENURE	2.235**	1.149	1.360	0.606	3.832***	2.754**	2.545**	0.607
	(0.963)	(0.954)	(0.956)	(0.954)	(1.093)	(1.090)	(1.095)	(1.124)
RD	-0.626	0.138	-0.502	-0.067	-0.420	0.008	-0.621	-0.233
	(0.917)	(0.914)	(0.920)	(0.903)	(1.093)	(0.873)	(0.884)	(0.872)
LEV	0.144	0.192*	0.163	0.112	0.171	0.204*	0.189*	0.134
	(0.110)	(0.110)	(0.112)	(0.112)	(0.107)	(0.107)	(0.109)	(0.107)
CAP	-1.996***	-1.958***	-1.986***	-1.739***	-1.973***	-1.916***	-1.927***	-1.740***
	(0.180)	(0.179)	(0.181)	(0.181)	(0.178)	(0.177)	(0.177)	(0.177)
DIV	-19.768***	-20.696***	-22.759***	-15.618***	-19.073***	-19.952***	-22.435***	-15.358***
	(4.003)	(4.000)	(4.023)	(4.031)	(3.752)	(3.767)	(3.816)	(3.801)
SIZE	-27.662***	-27.284	-31.089***	-34.648***	-26.895***	-26.373***	-29.905***	-34.175***
	(2.976)	(2.885)	(2.949)	(2.972)	(2.886)	(2.768)	(2.820)	(2.875)

Firm risk is measured as the standard deviation of daily stock returns over the last 90 trading days prior to each fiscal year-end (*$RISK_{90\ days}$*). See independent variable definitions in Section 3.3.2. CWZ: Cvitanic *et al*. (2008) model. BS: Black and Scholes (1973) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses. *, **, *** Significant at 10%, 5%, and 1%, respectiv

On the other hand, Tables 2 and 3 show that the TMT's wealth sensitivity to stock volatility has a positive impact on firm risk taking, which is in accordance with the prior literature (Guay, 1999; Rajgopal and Shevlin, 2002; Dong *et al*., 2010), because the option value increases with volatility. Moreover, the results indicate that specific corporate policies have an impact on firm risk taking. The number of business segments and net capital expenditure have a significant and negative effect on the level of firm risk (Coles *et al*., 2006), and this effect is robust to the risk measure used as the dependent variable. Other long-term policies, such as research and development expenditure, have a positive impact on the longer time horizon risk measure (Coles *et al*., 2006), while firm leverage impacts negatively (Armstrong and Vashishtha, 2012).

Tables 4 and 5 present the GMM results obtained from Equation (2). The difference between these tables is again the measure of firm risk and, as in Tables 2 and 3, we present results for the whole TMT and the TMT without the CEO. According to Hypothesis 2, non-gender diverse TMTs and those in which there is female representation should differ in the maximum wealth at risk at which the TMT's risk-increasing behavior turns into risk-decreasing behavior. In particular, we predict that, because of the higher risk aversion of females, the point of wealth at risk at which the risk behavior changes its direction is lower for gender diverse TMTs.

Table 4. GMM Estimation on the moderating role of TMT gender diversity on the relationship between TMT delta and firm risk (*$RISK_{5\ years}$*)

	Whole TMT				TMT without the CEO			
	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS
DELTA_TMT	15.046***	14.130***	12.341***	3.459	10.548***	9.516***	8.369***	5.260
	(2.218)	(2.486)	(2.534)	(2.224)	(1.469)	(1.581)	(1.581)	(3.941)
DELTA_TMT^2	-1.289***	-1.289***	-1.183***	-0.540	-0.910***	-0.897***	-0.821***	-0.575
	(0.162)	(0.181)	(0.185)	(0.379)	(0.120)	(0.129)	(0.130)	(0.401)
DELTA_TMT· GENDIV	-5.186***	-4.738***	-2.502***	-75.265	-3.485***	-3.253***	-3.987***	-44.038
	(1.193)	(11.288)	(11.342)	(76.946)	(0.896)	(0.541)	(0.767)	(28.705)
DELTA_TMT^2· GENDIV	-4.550***	-5.247***	-5.109***	5.042	-3.025***	-3.407***	-3.145***	3.252
	(0.710)	(0.779)	(0.779)	(3.442)	(0.588)	(0.612)	(0.608)	(5.320)
GENDIV	-2.014	-2.298	2.224*	2.443	-1.023	-1.052	-0.960	1.159
	(1.419)	(1.434)	(1.316)	(3.109)	(0.816)	(0.916)	(0.764)	(1.075)
VEGA_TMT	2.510***	1.424***	1.759***	5.604***	1.636***	0.807***	0.932***	2.112***
	(0.365)	(0.239)	(0.147)	(0.381)	(0.343)	(0.279)	(0.222)	(0.436)
DELTA_CEO					4.850***	4.570***	3.507***	0.065
					(1.183)	(1.259)	(1.262)	(1.569)
DELTA_CEO^2					-0.606***	-0.599***	-0.525***	-0.235*
					(0.098)	(0.105)	(0.106)	(0.125)
VEGA_CEO					1.210***	0.487**	0.879***	2.628***
					(0.284)	(0.231)	(0.195)	(0.400)
GENDER	-9.695*	-6.021	-11.186**	-13.866**	-1.849	-0.618	-7.107	-8.417
	(5.160)	(5.401)	(5.347)	(5.485)	(4.926)	(5.024)	(4.935)	(5.147)
CASHCOMP	-0.001***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
TENURE	0.052	-0.709**	-0.661**	-0.672**	0.946***	-0.000	-0.061	-0.210
	(0.292)	(0.307)	(0.301)	(0.301)	(0.328)	(0.344)	(0.339)	(0.352)
RD	3.065***	3.346***	3.044***	3.023***	2.993***	3.177***	2.901***	3.042***
	(0.264)	(0.280)	(0.276)	(0.272)	(0.257)	(0.270)	(0.268)	(2.267)
LEV	-0.125***	-0.115***	-0.147***	-0.146***	-0.112***	-0.106***	-0.140***	-0.154***
	(0.033)	(0.035)	(0.035)	(0.035)	(0.032)	(0.033)	(0.033)	(0.033)
CAP	-0.256***	-0.204***	-0.212***	-0.141**	-0.272***	-0.208***	-0.208***	-0.173***
	(0.054)	(0.058)	(0.057)	(0.057)	(0.053)	(0.056)	(0.055)	(0.055)
DIV	-4.348***	-3.423***	-3.663***	-2.674**	-2.832***	-2.328**	-2.509**	-1.988*
	(1.182)	(1.253)	(1.232)	(1.233)	(1.090)	(1.160)	(1.152)	(1.158)
SIZE	4.417***	5.835***	4.294***	3.559***	3.179***	4.819***	3.487***	2.957***
	(0.862)	(0.886)	(0.884)	(0.894)	(0.842)	(0.852)	(0.851)	(0.874)

Firm risk is measured as standard deviation of monthly firm stock returns over five years (*$RISK_{5\ years}$*). See independent variable definitions in Section 3.3.2. CWZ: Cvitanic *et al.* (2008) model. BS: Black and Scholes (1973) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses. *, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 5. GMM Estimation on the moderating role of TMT gender diversity on the relationship between TMT delta and firm risk (*$RISK_{90\ days}$*)

	Whole TMT				TMT without the CEO			
	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS	CWZ_L_1	CWZ_L_2	CWZ_L_3	BS
DELTA_TMT	5.891**	6.830**	5.413*	-41.665	4.742*	4.849*	4.938**	-10.517
	(2.893)	(3.280)	(3.102)	(26.726)	(2.805)	(2.578)	(2.303)	(7.611)
DELTA_TMT^2	-1.327**	-1.430**	-0.873**	1.968***	-0.926**	-0.964**	-0.769*	0.404
	(0.528)	(0.559)	(0.431)	(0.659)	(0.395)	(0.408)	(0.414)	(0.461)
DELTA_TMT· GENDIV	-2.584**	-1.955**	-2.745*	29.749	-1.788	-1.617	-1.271	-25.520
	(1.273)	(0.980)	(1.634)	(41.302)	(1.239)	(1.015)	(0.822)	(28.911)
DELTA_TMT^2· GENDIV	-2.949*	-2.589*	-1.389*	-0.957	-1.298*	-1.005**	-1.302*	2.135
	(1.745)	(1.484)	(0.730)	(2.759)	(0.753)	(0.482)	(0.763)	(2.178)
GENDIV	0.363	0.044	-0.518	-1.674	0.920	1.214	1.051	0.684
	(1.188)	(1.256)	(1.294)	(1.544)	0.797)	(0.788)	(0.798)	(0.967)
VEGA_TMT	1.971*	4.911***	4.807***	21.646***	-1.798	1.104	1.378*	5.735***
	(1.192)	(0.735)	(0.461)	(1.197)	(1.129)	(0.877)	(0.707)	(1.380)
DELTA_CEO					7.311*	8.839**	5.939	-14.233***
					(3.899)	(3.951)	(4.022)	(4.972)
DELTA_CEO^2					-1.334***	-1.454***	-1.148***	0.551
					(0.324)	(0.330)	(0.339)	(0.395)
VEGA_CEO					3.746***	3.916***	3.587***	13.738***
					(0.936)	(0.725)	(0.622)	(1.269)
GENDER	2.951	8.615	9.518	8.585	9.255	11.097	12.793	7.514
	(16.823)	(16.640)	(16.783)	(17.257)	(16.236)	(15.768)	(15.732)	(16.307)
CASHCOMP	-0.001	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
TENURE	2.100**	1.024	1.301	0.467	3.442***	2.329**	2.210**	0.358
	(0.953)	(0.946)	(0.945)	(0.947)	(1.083)	(1.080)	(1.082)	(1.114)
RD	0.182	0.853	0.221	0.350	0.391	0.786	0.199	0.540
	(0.862)	(0.864)	(0.867)	(0.857)	(0.846)	(0.846)	(0.853)	(0.846)
LEV	0.162	0.204*	0.171	0.125	0.166	0.198*	0.175*	0.133***
	(0.108)	(0.108)	(0.109)	(0.110)	(0.105)	(0.105)	(0.106)	(0.105)
CAP	-1.926***	-1.884***	-1.911***	-1.660***	-1.919***	-1.854***	-1.875***	-1.686***
	(0.177)	(0.177)	(0.178)	(0.179)	(0.176)	(0.175)	(0.176)	(0.175)
DIV	-19.863***	-20.964***	-23.087***	-16.239***	-17.936***	-18.773***	-20.976***	-14.686***
	(3.853)	(3.859)	(3.867)	(3.878)	(3.594)	(3.642)	(3.673)	(3.667)
SIZE	-24.844***	-24.799***	-28.211***	-32.266***	-24.689***	-24.388***	-27.785***	-31.939***
	(2.812)	(2.729)	(2.774)	(2.814)	(2.774)	(2.674)	(2.713)	(2.770)

Firm risk is measured as the standard deviation of daily stock returns over the last 90 trading days prior to each fiscal year-end (*$RISK_{90\ days}$*). See independent variable definitions in Section 3.3.2. CWZ: Cvitanic *et al.* (2008) model. BS: Black and Scholes (1973) model. L_1, L_2 and L_3 indicate different levels of the barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses. *, **, *** Significant at 10%, 5%, and 1%, respectively

Focusing on the results obtained, we can see that our independent variables continue to show the expected signs for the base term (positive effect) and its square (negative effect), which supports the inverted U-shaped relationship for those TMTs without female executives. When we add the multiplier effect of the variable that captures the TMT gender diversity to $DELTA\_TMT_{it}$ and its square, the significant and negative sign of both coefficients indicates that the maximum wealth at risk at which the TMT starts taking less risk is lower for those TMTs with female executives. These findings are robust for the two measures of firm risk, as well as for the whole TMT and the TMT without the CEO. Again, the BS model does not offer support for our hypothesis. In the same way as in Tables 2 and 3, when the CEO is not included as part of the TMT, they continue showing the concave relationship between ESO wealth and risk taking. Turning to the control variables, the results are similar to those obtained in Tables 2 and 3.

In the last two tables (Tables 6 and 7), we present the results of the different analyses that we conduct in order to deal with potential endogeneity issues regarding the moderating role of TMT gender diversity on the relationship between ESO wealth and firm risk taking. Our main goal is to ensure the robustness of the GMM results obtained in Tables 4 and 5. To simplify the calculation and the extension of the tables, we have considered delta and vega values calculated using the CWZ model and with the middle level of the barrier, that is, a barrier of 2 times the exercise price.

Table 6. 2SLS Estimation of the moderating role of TMT gender diversity on the relationship between TMT delta and firm risk

Second-stage regression results	Whole TMT		TMT without the CEO	
	RISK$_{5\ years}$	*RISK$_{90\ days}$*	*RISK$_{5\ years}$*	*RISK$_{90\ days}$*
	(1)	(2)	(3)	(4)
DELTA_TMT	18.715**	13.550**	9.456**	5.262**
	(8.624)	(6.696)	(4.717)	(2.482)
DELTA_TMT^2	-1.167**	-2.111**	-0.741**	-0.902**
	(0.562)	(0.985)	(0.355)	(0.408)
Instrumented DELTA_TMT·GENDIV	-3.709***	-4.398**	-1.460	1.051
	(1.375)	(2.027)	(2.100)	(1.634)
Instrumented DELTA_TMT^2·GENDIV	-1.375**	-2.733**	-1.898**	-1.127**
	(0.554)	(1.275)	(0.951)	(0.534)
Instrumented GENDIV	1.879	1.652	5.258	-2.229
	(1.482)	(1.561)	(7.261)	(5.147)
VEGA_TMT	2.276***	0.387	-0.568	0.215
	(0.236)	(0.406)	(0.510)	(0.512)
DELTA_CEO			1.227**	1.679*
			(0.544)	(0.927)
DELTA_CEO^2			-0.207**	-0.158**
			(0.095)	(0.071)
VEGA_CEO			0.237**	0.181*
			(0.115)	(0.099)
GENDER	-10.240**	-10.302	-2.647	2.199
	(4.882)	(8.218)	(3.233)	(5.210)
CASHCOMP	0.000	-0.000	-0.000*	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
TENURE	0.232	0.310	0.386	0.903
	(0.323)	(0.578)	(0.646)	(0.571)
RD	0.540***	0.017	0.116	-0.149
	(0.093)	(0.179)	(0.228)	(0.144)
LEV	0.041**	0.074**	0.046**	0.077***
	(0.017)	(0.032)	(0.020)	(0.028)
CAP	-0.207***	-0.508***	-0.307***	-0.355***
	(0.067)	(0.113)	(0.086)	(0.102)
DIV	-0.289	-1.327	1.677**	-1.115
	(0.464)	(0.876)	(0.748)	(0.734)
SIZE	1.056***	-2.039***	3.079***	-1.952***
	(0.254)	(0.491)	(0.731)	(0.411)

In the first-stage regressions, we estimate the predicted values of the endogenous variables (i.e., *GENDIV*, *DELTA_TMT·GENDIV*, and *DELTA_TMT^2·GENDIV*) by regressing each of them on the instrumental variable (i.e., *GENEQUALITY, DELTA_TMT·GENEQUALITY*, and *DELTA_TMT^2·GENEQUALITY*) and other controls. Firm risk is measured in columns 1 and 3 as the standard deviation of monthly firm stock returns over five years (*RISK$_{5\ years}$*), and in columns 2 and 4 as the standard deviation of daily stock returns over the last 90 trading days prior to each fiscal year-end (*RISK$_{90\ days}$*). See independent variable definitions in Section 3.3.2. To calculate Deltas and Vegas, we use Cvitanic *et al.* (2008) model with a level of the barrier equal to 2 times the exercise price. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.

*, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 7. Propensity score matching: the moderating role of TMT gender diversity on the relationship between TMT delta and firm risk

		Whole TMT		TMT without the CEO	
	Probit regression	$RISK_{5\,years}$	$RISK_{90\,days}$	$RISK_{5\,years}$	$RISK_{90\,days}$
	(1)	(2)	(3)	(4)	(5)
DELTA_TMT		7.423***	3.145*	4.603**	5.557**
		(2.256)	(1.755)	(1.832)	(2.185)
DELTA_TMT^2		-0.398**	-0.252**	-0.270*	-0.246**
		(0.158)	(0.122)	(0.152)	(0.119)
DELTA_TMT· DGENDIV		-1.003*	-1.034	2.818	0.219
		(0.553)	(2.514)	(2.388)	(4.600)
DELTA_TMT^2· DGENDIV		-0.099**	-0.835*	-0.274*	-0.145*
		(0.046)	(0.447)	(0.159)	(0.086)
DGENDIV		-3.665**	-1.527*	-8.188	-2.334
		(1.542)	(0.853)	(6.807)	(13.048)
VEGA_TMT		2.199***	1.499***	1.565***	-0.669
		(0.226)	(0.424)	(0.310)	(0.617)
DELTA_CEO				1.936*	3.287*
				(1.159)	(1.945)
DELTA_CEO^2				-0.085**	-0.288*
				(0.041)	(0.166)
VEGA_CEO				0.581**	0.461**
				(0.261)	(0.222)
CASHCOMP	0.000				
	(0.000)				
TENURE	-0.147**				
	(0.065)				
RD	-0.050***				
	(0.018				
LEV	0.003				
	(0.005)				
CAP	-0.004				
	(0.014)				
DIV	-0.243**				
	(0.121)				
SIZE	-0.342***				
	(0.030)				
Num. Obs.	4790	2614	2614	2614	2614

The dependent variable in the probit model is a TMT gender diversity dummy variable (*DGENDIV*). Results using the matched sample are presented in columns 2-5. The maximum difference in the propensity score does not exceed 0.1% in absolute value. Firm risk is measured in columns 2 and 4 as the standard deviation of monthly firm stock returns over five years ($RISK_{5\,years}$), and in columns 3 and 5 as the standard deviation of daily stock returns over the last 90 trading days prior to each fiscal year-end ($RISK_{90\,days}$). See independent variable definitions in Section 3.3.2. To calculate Deltas and Vegas, we use the Cvitanic *et al.* (2008) model with a level of the barrier equal to 2 times the exercise price. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.
*, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 6 presents results from the 2SLS estimation of firm risk taking (Equation 3) using as the exogenous instrumental variable the indicator of gender equality developed by Sugarman and Straus (1988). Using the predicted values of the endogenous variables from the first-stage regressions, the second-stage regression results are consistent with those obtained in the GMM approach. While there is a positive and significant relationship between $DELTA\_TMT_{it}$ and firm risk taking, the square of this variable has a negative impact on firm risk taking. Moreover, the negative sign of the coefficients of $Instrumented\, DELTA\_TMT \cdot GENDIV$ and $Instrumented\, DELTA\_TMT^2 \cdot GENDIV$ means that the point of wealth at risk at which the risk behavior changes its direction is lower for those TMTs with female executives.

Table 7 provides the results of the propensity score matching procedure described in the previous section. The maximum difference of the propensity score of the firm with gender diverse TMT and that of the non-gender diverse TMT does not exceed 0.1% (absolute value), as in Faccio *et al*. (2014). In this way, we restrict our sample to a set of peers; the two firms of each pair are virtually indistinguishable and only differ in the gender diversity of their TMTs. Column 1 reports the results of the probit regression of a TMT gender diversity dummy on firm and CEO characteristics. We can see that there is a negative relationship between the number of years that the CEO has been occupying that position and the probability that there are female executives in the TMT. As research and development expenditure, firm diversification and firm size increase, there is less probability that there are females in the TMT. As expected, the results in Columns 2-5 indicate that, after matching using a propensity score procedure, we continue to find statistically significant differences between gender diverse and non-gender diverse TMTs, because of the negative signs when we include the multiplier effect of the TMT gender diversity dummy.

The three different methodologies used in this study offer significant evidence of the more conservative behavior of gender diverse TMTs in relation to the risk taking impact of ESOs. To quantify the difference between the maximum point of wealth at risk of the inverted U-shaped relationship between non-gender diverse and gender diverse TMTs, we take the first derivative of the model represented in Equation (2) with respect to $DELTA\_TMT_{it}$, and making it equal to zero we obtain the expression $DELTA\_TMT_{it} = -(\beta_1 + \beta_1^* \cdot \overline{GD}) / 2(\beta_2 + \beta_2^* \cdot \overline{GD})$, where $\overline{GD}$ is the mean value of gender diversity in our sample. This is the breakpoint or point of inflection of the concave relationship and it depends on the significant coefficients. $\overline{GD}$ takes the value of zero for non-gender diverse TMTs and for the case of gender diverse TMT we make the maximum value of wealth at risk conditional to the mean value of TMT gender diversity. Thus, considering the whole TMT, the long-term risk measure and the middle level of the barrier in the CWZ model, the value of the maximum wealth at risk at which the risk-increasing behavior changes to risk-decreasing behavior is approximately $240,000 for non-gender diverse TMT and $75,000 for gender diverse TMTs.

In short, the results of the three different methodologies show, as expected, that there is a gender diversity gap in which non-gender diverse TMTs continue taking more risk and gender diverse TMTs adopt more conservative behavior by taking fewer risks, as Figure 2 in Section 2 shows. We conclude that our findings are consistent with our predictions, and therefore Hypothesis 2 is confirmed.

3.5. CONCLUSIONS

Although, since the 1980s stock options have become increasingly common in executive compensation packages (Murphy, 2013), there is still a lack of consensus regarding the effect of ESOs on risk taking behavior. Using six fiscal years of panel data (from June 2006 to May 2012) about TMTs of the S&P 1500, this study focuses on stock options awarded to the whole TMT in order to clarify their effects on firm risk. Moreover, this research also takes into account whether female representation in the TMT influences the relationship between ESOs granted to top management and firm risk taking, since the women's attitude to risk seems to differ from that of men.

By using the sensitivity of TMT wealth to stock price, or delta, using the valuation model of Cvitanic-Wiener-Zapatero (2008), and controlling for endogeneity, this study offers new evidence of the relationship between ESOs and firm risk. Taking into consideration the different perspectives of agency theory and BAM, and attempting to find an explanation for the lack of consensus in the prior literature, we predict and confirm the hypothesis regarding the existence of an inverted U-shaped relationship between the wealth of TMTs created by ESOs (current and prospective) and firm risk. Thus, the attitude toward risk of those top executives who receive ESOs is not linear and depends on their wealth at stake. They adopt risk-increasing behavior up to a certain point, where their risk bearing is high, and from that point they try to reduce their exposure to risk through less risky decisions. These findings are robust to the two measures of firm risk used in this study (the standard deviation of monthly firm stock returns during the five previous years and the standard deviation of daily stock returns over the last 90 trading day prior to each fiscal year-end). In addition, although our main concern is with the whole TMT, this study finds that when we separate the CEO from the TMT, both the CEO as an individual and the rest of the TMT as a group continue to show the inverted U-shaped relationship between ESO wealth and firm risk taking.

On the other hand, there is a substantial body of research, from the fields of economics, management and psychology, which focuses attention on gender-based differences with respect to behavior toward risk, suggesting that women are more risk and loss averse than men. In considering TMT gender diversity as a moderator of the ESO risk taking effect, this study goes beyond the previous studies. After controlling for potential endogeneity issues using different methodologies, our results show that TMTs in which there is no female representation are willing to bear more risk than gender diverse TMTs. In other words, the maximum wealth at risk provided by ESOs at which the TMT starts to take fewer risks is lower for gender diverse TMTs, which points to a more conservative behavior of mixed

TMTs. This leads us to point out that there is a gender diversity gap in which non-gender diverse TMTs continue taking more risk, consistent with the agency theory view, and gender diverse TMTs start with the risk-decreasing behavior predicted by the BAM view. This could indicate that when a company faces a significant level of risk, it is less likely to hire women for the TMT, since they are seen as being less willing to make risky decisions that might be necessary for the good conduct of the firm. (Mateos *et al.*, 2011)

Our results also highlight the limitations of the classical Black-Scholes (1973) model for identifying the risk taking behavior predicted by agency theory and BAM. Moreover, the findings from this study have other important implications for firms and boards of directors, and especially for compensation committees. First, shifting the research focus from the CEO to the level of the TMT creates new possibilities for increasing understanding of the entire TMT compensation effects on organizations (Baixauli-Soler and Sanchez-Marin, 2011; Henderson and Fredrickson, 2001). Second, when designing compensation packages, compensation committees should consider both the current and the prospective ESO wealth in order to attempt to increase or decrease the executive risk-taking behavior, depending on the firm's risk-related goals. Finally, compensation committees should take into account the gender-based differences related to risk aversion in order to make up appropriate compensation packages and incentives for both male and female executives. Our results indicate that it is not only important to look at the personal characteristics of top executives when implementing an optimal compensation design, but also that the gender diversity in the TMT is important, because of its significant impact on the behavior of the whole team, and therefore on decisions and strategies that are directly linked to the success of the firm.

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CHAPTER 4

GENDER, CORPORATE HIERARCHY AND FIRM RISK TAKING*

* An earlier version of this chapter was presented at the seminar "*Option-based executive compensation and risk taking: the moderating role of gender and corporate hierarchy*" held at University of Glasgow Adam Smith Business School (October 2014).

4.1. INTRODUCTION

Because it is an important component of governance practices, the interdisciplinary topic of executive compensation has received considerable attention from previous studies over decades (Jensen and Meckling, 1976; Gomez-Mejia and Wiseman, 1997; Goergen and Renneboog, 2011; Murphy, 1999, 2013) and, in particular, stock option-based compensation and its influence on executive risk behavior has been the subject of extensive research (Sanders, 2001; Wright *et al*., 2007; Sanders and Hambrick, 2007; Deutsch *et al*., 2010; Armstrong and Vashishtha, 2012).

Despite the growing body of research, as Devers *et al*. (2007) point out in their literature review, the empirical evidence on how executive stock options (ESOs) affect risk taking behavior remains unclear. Then, it is necessary to take a step forward in addressing the risk taking effect of ESOs by considering important aspects that may moderate such effect. First, consistent with the general view that women are more risk averse than men (Byrnes *et al*., 1999; Croson and Gneezy, 2009), the gender of the executive could have an influence on the ESO risk taking effect since, at the top management level, female executives also exhibit more conservative behavior compared to their male counterparts (Adhikari, 2012; Huang and Kisgen, 2013; Khan and Vieito, 2013). And second, the position within the top management team (TMT), that is, chief executive officers (CEOs) or non-CEO executives, may impact on the relationship between stock options and risk taking because of possible differences in risk propensity. For instance, the evidence shows that CEOs are more optimistic than chief financial officers (CFOs) (Graham *et al*., 2013) and that the power of CEOs may lead them to adopt riskier behavior (Fralich, 2012; Lewellyn and Muller-Kahle, 2012) than non-CEO executives.

The ambiguity about the empirical evidence, and the related mixed findings, extend also to the theoretical point of view. While in the classical framework of agency theory (Jensen and Meckling, 1976) ESOs are considered a useful tool in order to motivate executives to take more risk, overcoming problems related to risk aversion, the behavioral agency model (BAM) of managerial risk taking (Wiseman and Gomez-Mejia, 1998; Larraza-Quintana *et al*., 2007) concludes that ESOs can be associated with less risk taking. The difference between these two theoretical frameworks is that, as Martin *et al*. (2013) and Baixauli-Soler *et al*. (2014) indicate, agency theory bases its arguments on the positive effect of the prospective wealth (or the potential increase in intrinsic value) created by ESOs, while BAM builds its arguments on the negative effect of the perceived current wealth (or intrinsic value) created by ESOs.

Thus, the aim of this research is to contribute to a better understanding of the ESO risk taking effect by examining the moderating role of gender and executive category that, to the best of our knowledge, have not been addressed in previous studies. In particular, our starting point is that when they have a significant amount of stock options in their compensation packages, male and female executives, as well as CEOs and non-CEO executives, may react differently in terms of risk taking behavior. Furthermore, in an attempt to offer a more realistic explanation of the determinants and moderators of the ESO risk taking effect, we construct our hypotheses by combining agency and BAM arguments (Baixauli-Soler *et al*., 2014).

Drawing on this theoretical combination and employing panel data methodology for matched samples (Martin *et al*., 2009; Ertimur *et al*., 2011; Adhikari, 2012; Huang and Kisgen, 2013) of S&P 1500 listed firms during the fiscal years 2006-2011, this study makes several contributions to the literature. First, no previous research has focused on these two important factors in the relationship between option-based compensation and risk taking. Concerning gender and ESOs, previous studies have limited their interest to gender differences in the number of stock options within the compensation packages (Vieito and Khan, 2012), the value realized from exercising ESOs (Munoz-Bullon, 2010), or the time of exercising (Huang and Kisgen, 2013). On the other hand, regarding the position held in the corporate hierarchy, most of previous studies have focused on the figure of the CEO (Deutsch *et al*., 2010; Martin *et al*., 2013), without considering that non-CEO executives may react differently in terms of risk taking when they receive option grants. Second, unlike most previous studies that focus solely on either agency theory (Sanders, 2001; Deutsch *et al*., 2010) or BAM (Larraza-Kintana *et al*., 2007; Sawers *et al*., 2011), the mixed evidence encourages us to attempt to combine both theoretical perspectives and, in this way, show a better picture of the risk taking effect created by ESOs. Third, from the point of view of empirical testing, in addition to conducting the analysis with matched sample data, we control for potential endogeneity issues through Generalized Method of Moments (GMM) estimations and two-stage least squares (2SLS) instrumental variable estimations. Moreover, as the classical Black and Scholes (1973) model is appropriate for valuing exchange-traded options but not for ESOs (Hall and Murphy, 2003; Goergen and Renneboog, 2011), we use the completely analytical model developed by Cvitanic *et al*. (2008) which captures the particularities of ESOs (Alvarez-Diez *et al*., 2014).

The remainder of this chapter is organized as follows. Section 2 presents the theoretical framework and the research hypotheses. After that, Section 3 describes the sample, variables and the empirical methodology used. The empirical results are set out in the fourth section. And finally, in Section 5, we present the main conclusions of this chapter.

4.2. THEORETICAL FRAMEWORK AND HYPOTHESES

4.2.1. ESOs, gender and risk taking

Relationships between ESOs and risk taking can be better explained by focusing on both agency theory (Jensen and Meckling, 1976) and BAM (Wiseman and Gomez-Mejia, 1998). On the one hand, the agency perspective is in favour of granting stock options in order to align the interests of executives with those of shareholders and overcome executive risk aversion (Jensen and Meckling, 1976; Jensen and Murphy, 1990). Stock options allow executives to obtain benefits when the firm's stock price rises above the exercise price (unlimited upside potential), while the loss is capped at zero since they will not exercise their options if the stock price is below the exercise price. Thus, executives are willing to make riskier corporate decisions in search of increasing the firm's stock price and consequently the intrinsic value of their stock options, which is known as prospective wealth (Martin *et al*., 2013, Baixauli-Soler *et al*., 2014).

Nevertheless, the behavioral agency perspective (Wiseman and Gomez-Mejia, 1998) differs from classical agency theory. BAM postulates that stock options may discourage managerial risk taking since executives are loss averse, and therefore they prefer to protect their option's intrinsic value from possible loss rather than attempting to increase it. One of the most relevant concepts in BAM is the executive risk bearing and its negative influence on risk taking (Larraza-Kintana *et al*., 2007). Behavioral researchers state that the intrinsic value of the options is considered by executives as perceived current wealth and, due to their loss aversion, executives only want to preserve such wealth (Wiseman and Gomez-Mejia, 1998). As the intrinsic value escalates, the risk bearing also rises since there is more wealth at stake and therefore executives become even more risk averse (Larraza-Kintana *et al*., 2007; Sawers *et al*., 2012). In contrast with this, if the option value is set to zero, there is no wealth at risk (i.e., ESOs do not create risk bearing) and executives may be encouraged to take risks (Wiseman and Gomez-Mejia, 1998).

In that regard, Baixauli-Soler *et al*. (2014) recently confirmed the existence of an inverted U-shaped relationship between ESO wealth (current and prospective) and firm risk taking. If the intrinsic value is set to zero (out of the money options) or scarcely positive, the positive risk taking effect of prospective wealth (supported by agency theory) dominates the situation since executives will make higher-risk decisions searching for increasing the firm's stock price and, thus, their prospective wealth. As the intrinsic value and risk bearing escalates, the negative effect of the BAM view becomes stronger. In this case, the current wealth has a higher relative weight with respect to the prospective wealth and executives start to consider that their efforts in terms of risk taking may not lead to more increases in the firm's stock price. In this situation, executives will undertake lower-risk projects to protect their perceived current wealth from possible loss.

Incorporating gender in this relationship, the evidence highlights differences in risk propensity and, in particular, the prior literature is consistent with the view that women are more risk averse than men (for reviews see Byrnes *et al*., 1999; Croson and Gneezy, 2009; Bertrand, 2010). In this regard, both Charness and Gneezy (2012) and Halko *et al*. (2012) find that women invest less in risky assets than men. Barber and Odean (2001) show an annual portfolio turnover of 53% for men and 77% for women, which means that men trade more on financial markets than women. Using two separate computerized experiments, Powell and Ansic (1997) observe that women are both more risk and ambiguity averse than men, and therefore they make different financial decisions. Jianokoplos and Bernasek (1998) document that men's portfolios are riskier than those of women. Other experimental studies also show that, for instance, women are less likely to enter in a competition than men due to gender differences in confidence (Kamas and Preston, 2012) and because of the women's higher risk aversion and lower optimism regarding their relative performance (Niederle and Vesterlund, 2007). Differences in loss aversion (Schmidt and Traub, 2002), confidence and emotional reactions to risky situations (Croson and Gneezy, 2009) have been used to explain gender differences in the attitude toward risk.

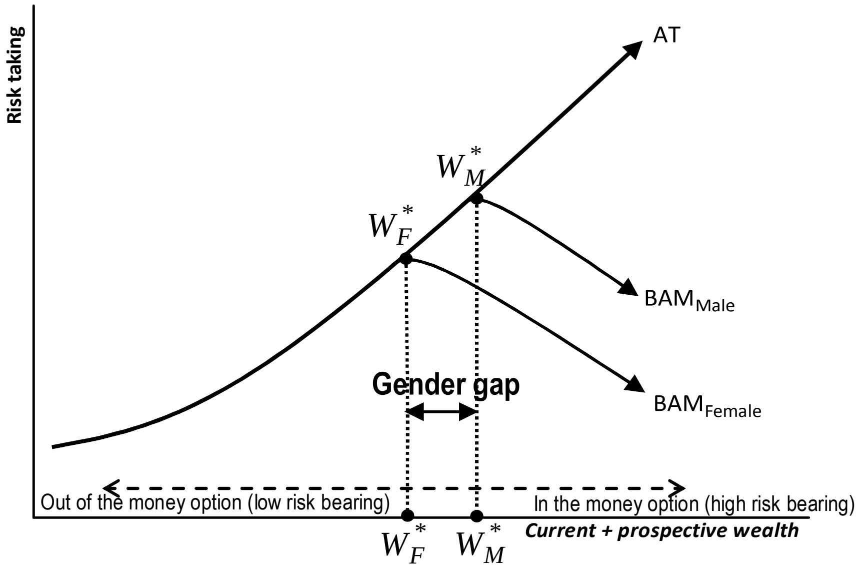
Although these arguments may apply to the general population, it could be reasonable to think that in the case of top management positions there are no gender differences in risk propensity. This might be due to the fact that the under-representation of women at this top level (Helfat *et al*., 2006; Dezso and Ross, 2012) may encourage female executives to adopt similar risk taking behavior to that of their male counterparts in order not to be fired, since those risky decisions or strategies may be essential for the good conduct of the firm. Furthermore, the fact of showing higher levels of risk aversion or adopting more conservative behavior could be detrimental for women when it is time to be hired by a firm in order to occupy any top management position which is related to risk taking (Mateos *et al*., 2011, 2012).

However, contrary to the above arguments, numerous recent studies find that gender differences in willingness to take risk are also evident in top management positions (Mohan, 2014). Some research has examined how the level of firm risk changes after female CEO appointments. Specifically, a change in CEO from man to woman leads to a reduction in the total firm risk, market risk and idiosyncratic risk (Martin *et al*., 2009), as well as several other measures of firm risk, such as firm leverage, research and development expenditure and the variability of cash flows (Elsaid and Ursel, 2011). These findings are consistent with the study of Khan and Vieito (2013), which offers evidence that when the CEO is a woman the firm risk level is smaller. Recently, it has been shown that female CEOs are associated with lower levels of leverage (Graham *et al*., 2013) and lower volatility of the firm's operating return on assets (Faccio *et al*., 2014), as well as higher levels of cash holding, lower capital expenditure and lower firm systematic risk (Adhikari, 2012). This means that female executives implement more conservative strategies and less risky corporate decisions compared to male executives. Evidence focused on the banking industry also reveals that female executives promote more conservative strategies and less risky financial decisions (Palvia *et al*., 2014).

Regarding gender and stock option-based compensation, previous studies show that while there are no significant differences between male and female executives with respect to the amount of stock options in their compensation packages (Munoz-Bullon, 2010; Vieito and Khan, 2012; Khan and Vieito, 2013), there are gender differences in the value of exercising the options. Using a sample of listed US firms over the period 1992-2006, Munoz-Bullon (2010) shows that the value from exercising stock options is lower for female executives than for male executives. More recently, in addition to showing that firms with female executives are less likely to make acquisitions or to issue debt, Huang and Kisgen (2013) examine gender differences in relation to the option exercise behavior of top executives. Although previous research studies show that early exercise of options is a common practice among top executives (Huddart and Lang, 1996; Bettis *et al*., 2005), Huang and Kisgen (2013) find that female executives are more likely to exercise ESOs early, which prior literature has shown to be related to risk aversion. In particular, they offer evidence that male executives are more likely to hold deep in-the-money options, hold ESOs in their compensation packages until the maturity date and buy the firm's stock.

Thus, gender differences in risk taking are reflected in the decisions that executives make, influencing the major strategic and financial decisions of their firms which directly impact on the level of firm risk (Palvia *et al*., 2014). The evidence shown in the literature leads us to expect a gender effect when we analyze the influence of option-based compensation on risk taking. Specifically, and drawing on the inverted U-shaped relationship between ESO wealth (current and prospective) and risk taking (Baixauli-Soler *et al*., 2014), we expect that the maximum wealth at risk that executives are willing to bear at which they change from risk-increasing behavior to risk-decreasing behavior differs according to gender. As shown in Figure 1, due to the higher female risk and loss aversion, female executives start taking less risk with a lower relative weight of the current wealth with respect to the prospective wealth (W_F*) compared to male executives (W_M*). In other words, female executives are not willing to bear as much risk as their male counterparts. This situation produces a gender gap in which female executives carry out lower-risk strategies consistent with the BAM view and male executives continue taking more risk in accordance with the agency theory.

Figure 1. The moderating role of executive gender on the ESO risk taking effect



Note: AT refers to Agency Theory

***Hypothesis 1**: The wealth at risk associated with a change in executive risk-taking behavior (from positive to negative) is lower for female executives.*

4.2.2. Corporate hierarchy and risk taking

As well as not considering the gender effect, most theoretical and empirical research into ESOs and risk taking has focused exclusively on the figure of the CEO (Sanders, 2001; Larraza-Quintana *et al*., 2007; Martin *et al*., 2013) without paying attention on the other executives who compose the TMT. However, in addition to the CEO, complex corporate strategies such as research and development investment (Alessandri and Pattit, 2014), financial decisions (Chava and Purnanandam, 2010) and firm risk taking in general (Wright *et al*., 2007) often involve non-CEO executives. Among the group of non-CEO executives, previous literature highlights the importance of the CFO in corporate decisions (Huang and Kisgen, 2013). Frank and Goyal (2010) show that the CFO is at least as important as the CEO for the firm's leverage choices. Not only does the CFO significantly affect the firm's financial policy (Chava and Purnanandam, 2010), but the CFO also exerts direct influence on the firm's investment policy (Bertrand and Schoar, 2003).

The complexity of managing large firms leads CEOs to delegate responsibilities to these other executives and trust in them (Sanders and Carpenter, 2002). Nevertheless, in spite of sharing responsibilities within a given firm, CEOs differ from non-CEO executives in several aspects such as their primary roles, their power, their level of compensation, their personal characteristics, career paths and attitudes (Graham *et al*., 2013), all of which may influence their risk taking propensity.

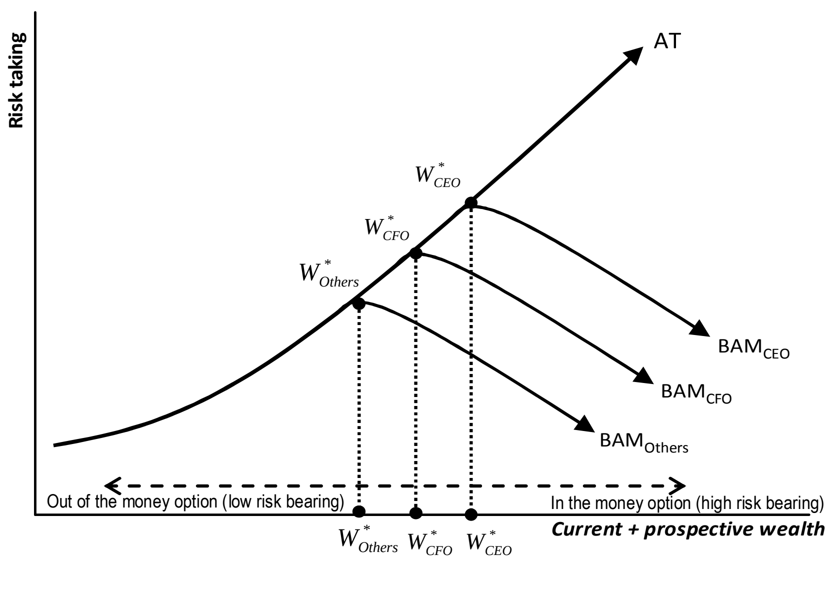
Regarding the role of the CEO, Hayward and Hambrick (1997) point out the importance of CEO hubris (exaggerated self-confidence) in the acquisition process, specifically concerning the size of premiums paid for acquisitions. These researchers remark that the support and approval of the CEO is essential for any decision related to large acquisitions. This power of the CEO may be extended to other important corporate decisions, such as those connected with compensation design. In this regard, Lambert *et al*. (1993: 441) define power as "the ability of managers to influence or exert their will or desires on the remuneration decisions made by the board of directors, or perhaps the compensation committee of the board". In particular, CEOs have influence not only over their own compensation, but also over the other top executives' compensation in terms of both level and structure (Carpenter and Sanders, 2002). The empirical research shows a clear divergence regarding how CEOs and other top executives are respectively paid receiving CEOs more cash, long-term and total compensation (Lambert *et al*., 1993; Henderson and Fredrickson, 2001; Carpenter and Sanders, 2002). Guay (1999) remarks that CEOs with higher cash compensation have more diversified portfolios since it is more likely that they invest part of their money outside the firm, and consequently they exhibit riskier behavior. On the other hand, CEOs have considerable power over non-CEO executives due to their formal corporate position within the organizational structure. This power allows the CEO to control, to a certain extent, the behavior and activities of the executives who belong to a lower level of the corporate hierarchy, and this control is greater as the CEO's structural power is greater (Finkelstein, 1992).

Connected with risk taking, studies in psychology support the hypothesis that power leads to greater risk taking. Through five experimental studies, Anderson and Galinsky (2006) examine the impact of possessing power on both risk perception and risk taking behavior. They find that possession of power is associated with an increased propensity to engage in risks since powerful people are more optimistic in assessing the probability of the downside risk. In other words, they are more optimistic in their risk estimates. Indeed, Graham *et al*. (2013) find that CEOs and CFOs differ in terms of attitudes, and particularly CEOs are more optimistic than CFOs. Lewellyn and Muller-Kahle (2012) focus on CEO power in the banking industry and show a significant and positive relationship between CEO power and risk taking. Furthermore, understanding prestige as a form of executive power, the evidence shows that, due to their superior ability to control resources, highly prestigious CEOs take more strategic risks than their lower-prestige counterparts (Fralich, 2012). In general, CEOs are significantly more risk-tolerant than the general population (Graham *et al*., 2013) and therefore it is logical to think that, due to their higher power, optimism and prestige compared with non-CEO executives, CEOs will be more prone to risk taking than CFOs and other executives.

In terms of strategic decision making, although non-CEO executives hold a relevant position within the firm, being powerful in some contexts and having specific business responsibilities, the CEO is almost always the most powerful TMT member and has overall responsibility for the conduct of the firm and performance outcomes (Bigley and Wiersema, 2002; Smith *et al*., 2006). Due to this responsibility, CEOs are risking their jobs with every strategic choice and the possibility of dismissal puts the CEO's future wages at risk (Fama, 1980). Based on the ideas of BAM, Larraza-Quintana *et al*. (2007) show that employment risk is associated with an increase in CEO risk preferences. Whether CEOs ultimately have more responsibility for the firm performance and decisions than non-CEO executives, their employment risk is more affected by negative signals of firm performance, and, therefore, CEOs will take more risk than non-CEO executives.

These arguments indicate that the position at the top management level could have an influence on the executive's proclivity for risks. Going back to the combination of agency theory and BAM, and taking into account the fact that previous research shows that possession of power, greater responsibilities and compensation, and employment risk impact positively on risk taking behavior, we expect that CEOs will be more willing to take risk when they are compensated with stock options compared to non-CEO executives. In the same way, it is likely that CFOs carry out riskier strategies and undertake riskier projects compared to lower-level executives. In summary, we suggest that the point of the relative weight of the current ESO wealth with respect to the prospective ESO wealth at which executives start taking less risk will be different depending on the position held in the corporate hierarchy. As shown in Figure 2, it is expected that as the position at the top management level decreases, that is, from CEOs to CFOs to other executives, the point of wealth at risk at which the risk-increasing behavior turns into risk-reducing behavior becomes lower.

Figure 2. The moderating role of executive category on the ESO risk taking effect



Note: AT refers to Agency Theory

***Hypothesis 2**: As the position at the top management level decreases, the wealth at risk associated with a change in executive risk-taking behavior (from positive to negative) decreases.*

4.3. METHODS

4.3.1. Data and sample

This study focuses on executives included in Standard and Poor's ExecuComp database. ExecuComp offers detailed data on stock options granted to the top five executives at each of the firms in the S&P 500, S&P MidCap 400 and S&P SmallCap 600. The time period analyzed in this study ranges from fiscal year 2006 to fiscal year 2011. ExecuComp database follows the Compustat year in which years ending from June of one year up to May of the following year constitute a "data year". Thus, the time period of our empirical analysis runs from June 2006 to May 2012. In addition, we obtain firm-specific information (accounting data and stock return information) from Compustat.

The ExecuComp database is the starting point for the formation of our matched sample. Without differentiating among the positions in the corporate hierarchy, the initial sample contains 24,604 executive-year observations of stock option portfolios based on 1,210 different firms. Of these observations, only about 6.2% correspond to female executives (1,523 female-year observations), which is consistent with the data shown in the literature (Helfat *et al.*, 2006; Muñoz-Bullon, 2010; Dezso and Ross, 2012). In order to overcome the problem of a small sample due to the scarce presence of women in top management positions, we follow prior literature and conduct the analyses by matching samples on the basis of industry, firm size and fiscal year (Martin *et al.*, 2009; Ertimur *et al.*, 2011; Adhikari, 2012). We separate three major executive categories: CEOs, CFOs, and Others. Obviously, the category of "Others" includes those executives who belong to the TMT and are neither the CEO nor the CFO. Within each of these three categories, each female-year observation is matched with three male-year observations in the S&P 1500 that belong to the same Fama-French industry, are closest in size in terms of total assets (firms within plus or minus 40 percent of the total assets), and in the same fiscal year. After the matching procedure, the final sample includes 6,093 executive-year observations (1,523 for female executives and 4,570 for male executives) based on 837 different firms. Of these observations, 543 correspond to CEOs, 1,740 correspond to CFOs and the category of "Others" consists of 3810 executive-year observations.

4.3.2. Variables

Firm risk taking (RISK). The dependent variable in the analysis is firm risk taking, measured as the standard deviation of firm's stock returns of the 60 months prior to the end of each fiscal year (Jin, 2002; Armstrong and Vashishtha, 2012; Vieito and Khan, 2012). This measure is the most accurate volatility estimator when using historical data (Alford and Boatsman, 1995).

Current and prospective ESO wealth (*DELTA*). Regarding the independent variables of interest, we measure the current and prospective ESO wealth as the sensitivity of executive wealth to changes in the firm's stock price (Baixauli-Soler *et al*., 2014). *DELTA* captures the option value, which is the sum of the current wealth (intrinsic value) and prospective wealth (temporal value), in a continuous way. Then, unlike Martin *et al*. (2013) who use two different variables to measure the effect of current and prospective wealth, the present study uses a single variable which combines both forms of ESO wealth. *DELTA* is defined as the rate of change of executive's equity portfolio value for a 1% change in the firm's stock price, which is consistent with previous studies (Core and Guay, 1999; Low, 2009; Dong *et al*., 2010; Fahlenbrach and Stulz, 2011). *DELTA* values are obtained by taking into account both the executive's option portfolio and stock portfolio (Brockman *et al*., 2010; Armstrong and Vashishtha, 2012, Coles and Li, 2013).

Other ESO incentives (*VEGA*). We also include in our models the stock option incentives to increase stock volatility, or *VEGA*. *VEGA* is defined as the rate of change of executive's option value for a 0.01 change in the stock return volatility. In this case, we only consider the executive's option portfolio (Rajgopal and Shevlin, 2002; Coles *et al*., 2006; Brockman *et al*., 2010; Coles and Li, 2013), since Guay (1999) shows that the vega of a stock portfolio is extremely small compared to that of an option portfolio. Consistent with the prior literature, we expect a positive relationship between VEGA and firm risk taking (Guay, 1999; Coles *et al*., 2006; Armstrong and Vashishtha, 2012).

In order to estimate *DELTA* and *VEGA* values, we use the Cvitanic *et al*. (2008) model (CWZ) since it captures the main particularities of ESOs (long term maturity, vesting period, early exercise, and job termination risk, among others). The expressions of *DELTA* and *VEGA* contain the basic inputs of classical option pricing models, which are the following: E = exercise price (ExecuComp), T = time to maturity (ExecuComp), S = the stock price at the end of each fiscal year (ExecuComp), σ = the annualized volatility (standard deviation of monthly returns over the last five years), r = risk-free interest rate (US Treasury bond yield at 10 year-constant maturity), q = dividend yield (Compustat). ExecuComp provides data on exercise prices and times to maturity for the most recent year's ESO grants, but not for ESO grants made in previous years. Because deltas and vegas of the entire option portfolio are the sum of both deltas and vegas of new grants and deltas and vegas of previously granted options, it is necessary to estimate the exercise price and time to maturity of those previously granted ESOs (both exercisable and unexercisable). To do that, we apply the methodology developed by Core and Guay (2002), which is widely used in the incentive compensation literature (Rajgopal and Shevlin, 2002; Low, 2009; Coles *et al*., 2006; Brockman *et al*., 2010; Fahlenbrach and Stulz, 2011; Gormley *et al*., 2013). With regard to the specific parameters of the CWZ model that capture the features of ESOs (vesting period, exit rate of executives, the barrier and its rate of decay used to capture the early exercise), we consider the values used in the recent study of Alvarez-Diez *et al*. (2014).

Executive's gender (*GENDER*). Gender is measured through a dummy variable that assumes a value equal to 1 if the executive is a woman, and zero in the case of a man (Vieito and Khan, 2012).

Firm and executive characteristics. Finally, we follow existing literature in selecting the observable characteristics that may influence firm risk taking (Coles *et al*., 2006; Brockman *et al*., 2010) and we include in our models the following control variables: cash compensation of executives (*CAHSCOMP*), defined as the sum of the executive's salary plus bonus; research and development expenditure (*RD*), defined as research and development expenditure scaled by total assets; net capital expenditure (*CAP*), defined as capital expenditure less sales of property, plant and equipment divided by total assets; leverage (*LEV*), defined as total book debt divided by the book value of assets; diversification (*DIV*), defined as the logarithm of the number of the firm's operating segments; and firm size (*SIZE*), defined as the logarithm of total assets.

4.3.3. Analysis

We employ panel data methodology which, in comparison with other methods, provides several advantages, including improvements in the econometric specifications and the parameter estimation by providing more information, more variability, less collinearity among the variables and more efficiency (Baltagi, 2001). Moreover, this methodology takes into account the fact that both firms and executives are heterogeneous, and there are always features affecting risk taking which are difficult to measure or to obtain that are not considered in the models. In order to avoid biased results, the panel includes an individual effect, η_i, which controls for the unobservable heterogeneity. Hence, the error term is $\varepsilon_{it}=\eta_i+\upsilon_{it}$, where υ_{it} is a random disturbance.

We must consider the potential endogeneity issues that are likely to be present in the empirical framework. On the one hand, while ESO incentives have an influence on executive risk taking as predicted in this study, it is obvious that causality is likely to run in the other direction since incentive compensation is arguably designed in anticipation of a particular risk environment (Coles *et al*., 2006; Armstrong and Vashishtha, 2012; Gormley *et al*., 2013; Alvarez-Diez *et al*., 2014). On the other hand, it is necessary to account for the endogenous relationship between gender and risk. As Huang and Kisgen (2013) and Baixuali-Soler *et al*. (2014) point out, female executives are not randomly assigned to firms. Firm risk taking and the view of higher female risk aversion may affect whether the firm attracts more female executives. It is possible that firms exclude women from those positions in which the willingness to take risk is a necessary ingredient or women may self-select into firms which are less related to risk taking (Mateos *et al*., 2011, 2012; Graham *et al*., 2013).

In the presence of endogeneity, the coefficients of the regressions are likely to be biased and empirical methodologies do not make it possible to quantify the magnitude of the economic effects of interest (Coles *et al*., 2006). Consequently, it is important to address the endogeneity issues in estimation. We attempt to resolve the endogeneity problem by estimating the models using the Generalized Method of the Moments (GMM) technique and, specifically, using the first-differenced GMM estimator proposed by Arellano and Bond (1991). These authors propose the use of GMM to instrumentalize the explanatory variables by using lagged values of the original regressors. In spite of being consistent for large panels, we do not apply the basic first-differenced two-stage least squares for panel data model of Anderson and Hsiao (1981) because the GMM technique exploits more moment conditions and therefore is asymptotically efficient. The model represented in Equation (1) is used to validate the two hypotheses of this chapter. The difference between these two hypotheses is the sample used to test each of them. To test Hypothesis 1, we employ the total sample, while we use the samples of CEOs, CFOs and "Others" to test Hypothesis 2. It can be observed that this model includes DELTA and its square in order to test the concave relationship between delta and risk taking, as well as the main effect and the multiplier effect of the variable that captures the executive's gender[1].

$$
\begin{aligned}
RISK_{it} &= \beta_0 + \left(\beta_1 + \beta_1^{*} \cdot GENDER_{it}\right) DELTA_{it} \\
&+ \left(\beta_2 + \beta_2^{*} \cdot GENDER_{it}\right) DELTA_{it}^{2} + \beta_3 \cdot GENDER_{it} + \beta_4 \cdot VEGA_{it} \\
&+ \beta_5 \cdot CASHCOMP_{it} + \beta_6 \cdot RD_{it} + \beta_7 \cdot CAP_{it} + \beta_8 \cdot LEV_{it} + \beta_9 DIV_{it} + \eta_{it} + \upsilon_{it}
\end{aligned}
\qquad (1)
$$

For robustness, and following with the aim of addressing endogeneity in statistical analyses, we also conduct an exogenous instrumental variable approach based on the index of state-level gender equality proposed by Sugarman and Straus (1988). These researchers construct indicators of gender equality for each of the 50 US states. Following Huang and Kisgen (2013) and Palvia *et al*. (2014), the higher the score assigned to a state, the more friendly a state is to women's equality, and therefore the more likely a firm headquartered in that state is to have a female executive. This variable (*GENEQUALITY*) should not have a direct effect on firm risk taking, but is correlated with the presence of female executives at the top management level of the firm headquartered in that state. This leads to the validity of the instrument. In this case, we estimate the models using a two-stage least squares (2SLS) regression analysis. In the first stage, the endogenous variables (i.e., *GENDER*, *DELTA·GENDER*, and *DELTA²·GENDER*) are regressed on the instrument (i.e., *GENEQUALITY*, *DELTA·GENEQUALITY*, and *DELTA²·GENEQUALITY*, respectively) and predetermined variables. In the second stage, the measure of firm risk taking is regressed on the predicted values of the endogenous variables obtained in the first stage (*Instrumented GENDER*, *Instrumented DELTA·GENDER*, and *Instrumented DELTA²·GENDER*), as well as the other exogenous controls (Equation 2). Like Equation (1), Equation (2) is used to validate Hypotheses 1 and 2, and the difference is the sample used to test each of them.

[1] When we analyze the position of the CEO, we include in the model CEO tenure (*TENURE*), which is measured as the logarithm of the number of years that the CEO has held such position (Armstrong and Vashishtha, 2012; Baixauli-Soler *et al*., 2014).

$$\begin{aligned} RISK_{it} &= \beta_0 + \beta_1 \cdot DELTA_{it} + \beta_1^* InstrumentedDELTA_{it} \cdot GENDER_{it} \\ &+ \beta_2 \cdot DELTA_{it}^2 + \beta_2^* \cdot InstrumentedDELTA_{it}^2 \cdot GENDER_{it} \\ &+ \beta_3 \cdot InstrumentedGENDER_{it} + \beta_4 \cdot VEGA_{it} + \beta_5 \cdot CASHCOMP_{it} \\ &+ \beta_6 \cdot RD_{it} + \beta_7 \cdot CAP_{it} + \beta_8 \cdot LEV_{it} + \beta_9 DIV_{it} + \eta_{it} + \upsilon_{it} \end{aligned} \tag{2}$$

Finally, to further ascertain the robustness of the results obtained with the matched sample on the basis of industry, firm size and fiscal years, and following previous research studies (Ertimur *et al*., 2011; Huang and Kisgen, 2013; Carter *et al*., 2014; Faccio *et al*., 2014; Palvia *et al*., 2014), we employ a propensity score procedure to obtain the matched sample (Rosenbaum and Rubin, 1983). In this way, each female-year observation is paired with a male-year observation, and both executives belong to firms that are virtually indistinguishable in terms of observable characteristics. First, we compute a propensity score using a Probit model (Equation 3), where the female dummy variable (*GENDER*) is regressed on all those observable characteristics that are economically meaningful, which are cash compensation, CEO tenure, research and development expenditure, net capital expenditure, diversification, leverage, firm size, the index of state-level gender equality proposed by Sugarman and Straus (1988), and year dummies. Following Faccio *et al*. (2014), the maximum difference between the propensity score of the firm with the female-year observation and that of its matching peer cannot exceed 0.1% (absolute value). In that way, each female-year observation is paired with a male-year observation with statistically the same characteristics. After that, we conduct regressions with the matched sample using *GENDER* and the rest of variables of interest (Equation 4).

$$\begin{aligned} GENDER_{it} &= \beta_1 \cdot CASHCOMP_{it} + \beta_2 \cdot TENURE + \beta_3 \cdot RD_{it} + \beta_4 \cdot CAP_{it} + \beta_5 \cdot LEV_{it} \\ &+ \beta_6 \cdot DIV + \beta_7 \cdot SIZE + \beta_8 \cdot GENEQUALITY + \eta_{it} + \upsilon_{it} \end{aligned} \tag{3}$$

$$\begin{aligned} RISK_{it} &= (\beta_1 + \beta_1^* \cdot GENDER_{it})DELTA_{it} + (\beta_2 + \beta_2^* \cdot GENDER_{it})DELTA_{it}^2 \\ &+ \beta_3 \cdot GENDER_{it} + \beta_4 \cdot VEGA_{it} + \eta_{it} + \upsilon_{it} \end{aligned} \tag{4}$$

4.4. RESULTS

Table 1 provides descriptive statistics for all the variables used in this study. Panel A of Table 1 presents summary statistics on firm-specific characteristics for the full sample. As can be seen, the mean level of firm risk is about 36%, the mean value of research and development expenditure is 2.01%, and the mean capital expenditure and leverage are 4.27% and 21.25%, respectively. Regarding the level of firm diversification, the US firms included in the sample have on average 2.5 operating segments and the average natural logarithm of total assets is 7.77. These summary statistics for firm characteristics are consistent with those reported in Baixauli-Soler *et al*. (2014).

For the three major executive categories considered in this study, Panel B of Table 1 reports the mean values of executive-specific characteristics related to their own compensation: deltas, vegas and cash compensation. As far as deltas and vegas are concerned, we provide three different values corresponding to three different levels of the barrier considered in the CWZ framework in order to capture the early exercise behavior. Specifically, L_1, L_2 and L_3 refer to 1.5, 2 and 2.5 times the exercise price of the options (Alvarez-Diez *et al*., 2014; Baixauli-Soler *et al*., 2014). Without differentiating among executive categories, the mean sensitivity of male executive wealth to stock price ranges from $215,510 to $237,440 for the highest and the lowest level of the barrier considered, respectively. On the other hand, a 0.01 increase in the standard deviation of returns results in a mean increase in the male executive wealth of $56,990 for a barrier of 1.5 times the exercise price and $67,540 in the case of the barrier of 2.5 times the exercise price. These figures are in line with those obtained by Coles and Li (2013), who do not differentiate between CEOs and other top executives and consider the top-five executives from ExecuComp.

Table 1. Descriptive statistics

Panel A: Firm characteristics

	Mean	SD	10th percentile	Median	90th percentile
RISK[a]	36.07	14.41	20.56	33.36	54.67
RD[a]	2.01	4.45	0.00	0.00	7.79
CAP[a]	4.27	4.35	0.39	3.05	9.50
LEV[a]	21.25	18.10	0.00	19.44	44.88
DIV[b]	0.92	0.70	0.00	1.10	1.79
SIZE[b]	7.77	1.65	5.85	7.52	10.17

Panel B: Executive characteristics

	All executives		CEOs		CFOs		Others	
	Female	Male	Female	Male	Female	Male	Female	Male
DELTA_L_1[c]	130.54	237.44	299.16	880.12	124.08	202.69	110.64	160.45
DELTA_L_2[c]	124.30	221.03	293.85	801.68	115.99	190.94	104.89	150.81
DELTA_L_3[c]	119.98	215.51	300.51	760.99	107.83	185.05	100.41	150.65
VEGA_L_1[c]	44.97	56.99	105.66	193.62	42.20	45.54	37.97	42.66
VEGA_L_2[c]	57.95	68.59	130.22	218.31	66.81	55.28	45.56	53.28
VEGA_L_3[c]	59.85	67.54	150.62	203.32	62.19	52.88	47.21	54.96
CASHCOMP[c]	523.31	655.82	986.78	1048.26	546.16	565.36	532.00	617.69
TENURE[b]			1.37	1.87				

Panel A reports descriptive statistics of firm characteristics. Panel B presents mean values of executive characteristics. See variable definitions in Section 4.3.2. L_1, L_2, and L_3 indicate different levels of the CWZ barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. SD: standard deviation. [a]: percentage. [b]: logarithm. [c]: \$000s.

In Panel B of Table 1, it can be observed that there are differences in delta and vega values between male and female executives. On average, the wealth of female executives is less sensitive to changes in stock price and stock return volatility than that of their male counterparts. This means that female executives are less likely to accept riskier compensation packages, which is consistent with the recent empirical research of Carter *et al.* (2014). As these researchers point out, the greater risk aversion of female executives may be the reason for having compensation packages subject to less risk through lower incentive levels (lower deltas and vegas). Moreover, we find that CEOs have higher incentive levels in their compensation packages than non-CEO executives, which is also in accordance with prior studies (Chava and Purnanandam, 2010; Fahlenbrach and Stulz, 2011; Anantharaman and Lee, 2014). As the position within the corporate hierarchy decreases from CEOs to CFOs and to other executives, both deltas and vegas decrease and the differences between male and female executives within each level of the corporate hierarchy become smaller. Thus, these findings highlight the fact that more risk averse executives, including female executives compared to male executives and non-CEO executives compared to CEOs, tend to have lower deltas and vegas in their compensation packages. Finally, CEOs receive more cash compensation than non-CEO executives (Henderson and Fredrickson, 2001; Carpenter and Sanders, 2002), and within each of the executive categories the gender pay gap remains (Bertrand and Hallock, 2001; Muñoz-Bullon, 2010). According to Carter *et al*. (2014), although the pay gap related to cash compensation has declined significantly over time, the gender incentive gap has not followed the same pattern and continues to be important, as Panel B of Table 1 indicates.

The empirical results are shown from Table 2 to Table 5. Table 2 presents the gender effect on the relationship between stock option incentives and risk taking, which corresponds to Hypothesis 1. This table shows results obtained through the GMM technique (Columns 1-3) and the 2SLS instrumental variable approach (Columns 4-6).

According to Hypothesis 1, the maximum wealth at risk that executives are willing to bear at which they change from risk-increasing behavior to risk-decreasing behavior differs according to gender because of differences in risk propensity, which is lower for female executives. Focusing on the GMM results, for the three levels of the barrier considered, the coefficient of *DELTA* is positive and significant, while the coefficient of its square is negative and significant, which supports the existence of the inverted U-shaped relationship found by Baixauli-Soler *et al*. (2014). Moreover, when we add the gender effect on both *DELTA* and its square, we must focus on the significant coefficients, which we use to obtain the different points of inflection of the concave relationship. In particular, the significant and negative sign of β_2^* causes that the maximum wealth at risk at which the executive adopts risk-reducing behavior, after riskier behavior, is lower for female executives, which supports Hypothesis 1.

Table 2. GMM and 2SLS Estimation of the influence of executive's gender on ESO risk taking effect

	GMM Estimation			2SLS Estimation *(Second-stage regression results)*		
	L_1	L_2	L_3	L_1	L_2	L_3
	(1)	(2)	(3)	(4)	(5)	(6)
DELTA	0.037***	0.036***	0.036***	0.450*	0.406*	0.473*
	(0.001)	(0.007)	(0.007)	(0.258)	(0.244)	(0.244)
$DELTA^2$	-0.003***	-0.003***	-0.003***	-0.038***	-0.035***	-0.041***
	(0.001)	(0.001)	(0.001)	(0.010)	(0.010)	(0.010)
DELTA· GENDER[a]	0.014	0.014	0.020	0.567	0.545	0.569
	(0.016)	(0.013)	(0.017)	(0.390)	(0.351)	(0.366)
$DELTA^2$· GENDER[b]	-0.001***	-0.001***	-0.001***	-0.008**	-0.007*	-0.008*
	(0.000)	(0.000)	(0.000)	(0.004)	(0.004)	(0.004)
GENDER[c]	-0.073**	-0.085***	-0.137***	-2.907***	-1.255***	-0.907**
	(0.034)	(0.029)	(0.035)	(0.745)	(0.452)	(0.363)
VEGA	0.011***	0.002	0.009***	0.021***	0.026***	0.023***
	(0002)	(0.002)	(0.002)	(0.003)	(0.006)	(0.004)
CASHCOMP	-0.004*	-0.002	-0.001	0.003	-0.004	-0.004
	(0.002)	(0.002)	(0.002)	(0.004)	(0.005)	(0.004)
RD	0.068	0.066	0.052	0.030	0.029	0.021
	(0.048)	(0.047)	(0.046)	(0.064)	(0.060)	(0.074)
CAP	-0.015	-0.028	-0.023	-0.049	-0.034	-0.010
	(0.026)	(0.025)	(0.026)	(0.057)	(0.055)	(0.030)
LEV	0.060***	0.055***	0.052***	0.026**	0.021**	0.022*
	(0.010)	(0.001)	(0.009)	(0.012)	(0.011)	(0.012)
DIV	-0.003	-0.004*	-0.006**	-0.007**	-0.005*	-0.005
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Constant	0.361***	0.362***	0.383***	1.135***	0.708***	0.545***
	(0.027)	(0.024)	(0.026)	(0.201)	(0.225)	(0.102)

The dependent variable, firm risk taking, is measured as the standard deviation of monthly stock returns over the last five years. See independent variable definitions in Section 4.3.2. L_1, L_2, and L_3 indicate different levels of the CWZ barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). In the first stage of 2SLS Estimation, the endogenous variables (i.e., *GENDER*, *DELTA·GENDER*, and *$DELTA^2$·GENDER*) are regressed on the instrument (i.e., *GENEQUALITY*, *DELTA·GENEQUALITY*, and *$DELTA^2$·GENEQUALITY*) and predetermined variables. [a]: In 2SLS Estimation, this variable is its respective instrumented variable (Instrumented DELTA·GENDER). [b]: In 2SLS Estimation, this variable is its respective instrumented variable (Instrumented $DELTA^2$·GENDER). [c]: In 2SLS Estimation, this variable is its respective instrumented variable (Instrumented GENDER). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.

*, **, *** Significant at 10%, 5%, and 1%, respectively

Given the values of the estimated coefficients, to obtain the turning points for male executives (W_M^*) and female executives (W_F^*) that can be seen in Figure 1, we take the first derivative of the model represented in Equation (1) with respect to *DELTA* and make it equal to zero. The breakpoint of the quadratic relation is $DELTA_{it} = -\left(\beta_1 + \beta_1^* \cdot GENDER\right) / \left(2\left(\beta_2 + \beta_2^* \cdot GENDER\right)\right)$. As can be observed, this expression depends on the executive's gender measured by the dummy variable (*GENDER*). In the case of male executives (*GENDER* equals 0), the breakpoint is $DELTA_{it} = -\beta_1 / 2\beta_2$, while the expression of the point of inflection for female executives (*GENDER* equals 1) is $DELTA_{it} = -\left(\beta_1 + \beta_1^*\right) / \left(2\left(\beta_2 + \beta_2^*\right)\right)$.

Focusing on the GMM results obtained in Table 2, and taking into account that only significant coefficients can be included in the above expressions, W_M^* exceeds W_F^* for all early exercise barriers considered. Making the average of the maximum values calculated for the three barriers, the value of the maximum wealth at risk at which the risk-increasing behavior changes to risk-reducing behavior is approximately $227,000 for male executives and $57,000 for female executives, confirming Hypothesis 1. These findings indicate that the executive's risk bearing depends on their level of risk aversion and therefore, because of the higher female risk aversion, females executive are not willing to bear as much risk as their male counterparts when they receive stock options.

Moreover, the main effect of the gender variable shows that female executives are associated with lower levels of firm risk (Martin *et al.*, 2009; Elsaid and Ursel, 2011; Khan and Vieito, 2013), which again supports the common assertion of lower risk propensity among female executives. With regard to the rest of the variables included in the models, it can be seen that, for the majority of the early exercise barriers considered, vega is significant in taking more risks. The greater the sensitivity of executive wealth to stock return volatility, the more risks are taken, and this positive effect is widely documented in the literature (Rajgopal and Shevlin, 2002; Low, 2009; Armstrong and Vashishtha, 2012). There is no doubt that vega is an essential variable in relation to managerial risk incentives. In addition, the results show that more diversified firms are associated with lower levels of risk and that higher levels of leverage impact positively on firm risk taking (Coles *et al*., 2006; Brockman *et al*., 2010).

Through the 2SLS instrumental variable estimation, using the predicted values of the endogenous variables from the first-stage regressions (*Instrumented GENDER*, *Instrumented DELTA·GENDER*, and *Instrumented* $DELTA^2$*·GENDER*), the second-stage regression results shown in the last three columns of Table 2 give robustness to the GMM results. The negative and significant sign of the coefficient of *Instrumented* $DELTA^2$*·GENDER* means that that the point of wealth at risk at which executives start taking less risk is lower for female executives. Thus, as can be observed in Figure 1, there is a gender gap in which male executives continue with the risk-increasing behavior, as predicted by agency theory, and female executives adopt risk-decreasing behavior because of their risk bearing, and this is consistent with the BAM view.

Table 3. GMM Estimation of the influence of corporate hierarchy on ESO risk taking effect

	CEOs			CFOs			Others		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
DELTA	0.040***	0.038***	0.040***	0.026***	0.023***	0.025***	0.015**	0.016*	0.016**
	(0.005)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)	(0.001)	(0.007)
$DELTA^2$	-0.003***	-0.003***	-0.003***	-0.003***	-0.002***	-0.002***	-0.002**	-0.002**	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DELTA·GENDER	0.011	0.013	0.015	0.019**	0.021***	0.020***	0.072	0.0723	0.089
	(0.019)	(0.011)	(0.017)	(0.008)	(0.007)	(0.007)	(0.044)	(0.048)	(0.055)
$DELTA^2$·GENDER	-0.001**	-0.001**	-0.001**	-0.003**	-0.003**	-0.003**	-0.009	-0.008	-0.010
	(0.000)	(-0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.016)	(0.017)	(0.023)
GENDER	-0.148***	-0.094***	-0.047**	-0.127***	-0.196***	-0.181***	-0.119*	-0.084	-0.155**
	(0.045)	(0.037)	(0.019)	(0.024)	(0.024)	(0.016)	(0.061)	(0.060)	(0.076)
VEGA	0.042***	0.027***	0.003***	0.023***	0.015***	0.004**	0.014***	0.017***	0.016***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
CASHCOMP	-0.004	-0.003	-0.001	0.031	0.028	0.011	-0.000	-0.001	-0.001
	(0.003)	(0.003)	(0.002)	(0.025)	(0.024)	(0.024)	(0.002)	(0.001)	(0.002)
TENURE	-0.008	0.004	-0.006						
	(0.005)	(0.005)	(0.004)						
RD	-0.007	0.081	0.095	0.848	0.880	0.822	0.136	0.097	0.095
	(0.057)	(0.051)	(0.064)	(0.897)	(0.930)	(0.852)	(0.085)	(0.090)	(0.078)
CAP	-0.254***	-0.276***	-0.356***	-0.103	-0.071	-0.114	-0.013	-0.009	-0.012
	(0.038)	(0.039)	(0.038)	(0.072)	(0.071)	(0.083)	(0.025)	(0.023)	(0.025)
LEV	0.045***	0.039***	0.037***	0.091***	0.097***	0.115***	0.055***	0.039***	0.035***
	(0.002)	(0.008)	(0.009)	(0.017)	(0.016)	(0.015)	(0.010)	(0.008)	(0.008)
DIV	-0.007***	-0.014***	-0.014***	-0.024***	-0.016***	-0.005**	-0.006***	-0.006***	-0.005***
	(0.002)	(0.002)	(0.001)	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.517***	0.499***	0.559***	0.185***	0.270***	0.372***	0.480***	0.462***	0.479***
	(0.027)	(0.30)	(0.028)	(0.037)	(0.033)	(0.028)	(0.027)	(0.022)	(0.021)

The dependent variable, firm risk taking, is measured as the standard deviation of monthly stock returns over the last five years. See independent variable definitions in Section 4.3.2. L_1, L_2, and L_3 indicate different levels of the CWZ barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.
*, **, *** Significant at 10%, 5%, and 1%, respectively

Tables 3 and 4 present the results for the moderating role of the position occupied by the executive at the top management level on the ESO risk taking effect. Results from these tables make it possible to test Hypothesis 2. As in Table 2, we continue showing results from the three levels of the early exercise barrier for each of the major executive categories analyzed in this study: CEOs, CFOs and other executives. Focusing on the GMM results shown in Table 3, it can be observed that while β_1 is positive and significant, β_2 is negative and significant for all major executive categories, which means that the inverted U-shaped relationship found by Baixauli-Soler *et al*. (2014) between delta values and risk taking exists in all the executive categories considered. According to Hypothesis 2, because of the higher risk propensity of the CEO compared to non-CEO executives, the maximum point of wealth at risk associated which a change of risk taking behavior (from positive to negative) is lower as the position in the corporate hierarchy decreases.

To test Hypothesis 2, we must calculate the breakpoints of the concave relationships, and the approach and expressions of these maximum points are the same than those used to test Hypothesis 1 in Table 2. Thus, taking into account the significant coefficients (β_1 and β_2 in all cases, β_2^* for the case of CEOs, and β_1^* and β_2^* for the case of CFOs) and calculating the average obtained through the three barriers, the points of wealth at risk at which the risk-increasing behavior turns into risk-reducing behavior are the following: \$496,000 for male CEOs, \$108,000 for female CEOs, \$157,000 for male CFOs, \$73,000 for female CFOs, and \$50,000 for other executives (males and females). Analysing these findings, it can be observed that focusing on male executives, the maximum delta value from which male executives start taking less risk becomes smaller as the executive category decreases from CEOs to CFOs to other executives. This pattern can also be observed in the case of female executives. These findings support Hypothesis 2. In this way, these findings provide new evidence in support of the greater willingness to take risk on the part of CEOs after being awarded with stock options than executives who do not have the same power, prestige or responsibilities within the firm.

On the other hand, Table 3 also allows us to examine gender differences within each of the executive categories. We find that the gender gap confirmed in Hypothesis 1 is lower as the position held by the executive decreases. In particular, while this gender gap is higher for CEOs compared to that of CFOs, in the case of the category of "Others" β_1^* and β_2^* are not significant, which means that the maximum wealth at risk at which the executive risk behavior changes does not differ significantly between male and female executives at this lower category. It can be concluded that greater gender differences in the risk taking effect of stock options are present at the top of the corporate hierarchy (for CEOs), but are less for CFOs. But with respect to other executives, male and female executives are willing to bear the same level of risk and exhibit similar risk taking behavior caused by the stock options of their compensation packages.

Regarding the other variables included in the models, similar results to those obtained in Table 2 are found, in particular with respect to the main effect of gender, vega, leverage and firm diversification on the level of firm risk. In addition, in the analysis of the category of CEOs, capital expenditure has a negative impact on firm risk, which is consistent with previous studies that show the negative effect of this low-risk corporate policy (Coles *et al*., 2006).

Concerning the exogenous instrumental variable approach, using the indicator of gender equality developed by Sugarman and Straus (1988), Table 4 presents results from the 2SLS estimation. Although β_1^* in the case of CFOs is not significant, the conclusions from Table 4 are unchanged. As the executive position in the corporate hierarchy decreases, the point of wealth at risk at which executives start taking less risk, consistent with the BAM arguments, becomes smaller, re-affirming the GMM results shown in Table 3.

Table 4. 2SLS Estimation of the influence of corporate hierarchy on ESO risk taking effect

(Second-stage regression results)	CEOs			CFOs			Others		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
DELTA	0.582**	0.545**	0.561**	0.274*	0.254*	0.257*	0.206**	0.184*	0.205*
	(0.238)	(0.254)	(0.268)	(0.152)	(0.123)	(0.151)	(0.103)	(0.099)	(0.106)
$DELTA^2$	-0.045***	-0.042**	-0.043**	-0.029**	-0.026**	-0.027**	-0.023*	-0.021**	-0.023**
	(0.017)	(0.018)	(0.018)	(0.013)	(0.011)	(0.013)	(0.012)	(0.011)	(0.011)
InstrumentedDELTA·GENDER	-0.122	0.082	0.208	0.062	0.075	0.070	0.079	0.064	0.092
	(0.513)	(0.562)	(0.547)	(0.276)	(0.253)	(0.286)	(0.227)	(0.194)	(0.231)
InstrumentedDELTA²·GENDER	-0.014**	-0.019***	-0.016**	-0.012*	-0.016*	-0.014*	-0.098	-0.079	-0.071
	(0.006)	(0.007)	(0.007)	(0.008)	(0.009)	(0.009)	(0.080)	(0.076)	(0.082)
InstrumentedGENDER	-3.226**	-1.106**	-1.418**	-1.157***	-1.544***	-1.004**	-1.446***	-1.179***	-1.341***
	(1.505)	(0.498)	(0.629)	(0.445)	(0.500)	(0.465)	(0.415)	(0.454)	(0.466)
VEGA	0.020**	0.030**	0.018**	0.031***	0.015**	0.026*	0.017**	0.021**	0.019***
	(0.010)	(0.013)	(0.008)	(0.011)	(0.006)	(0.014)	(0.007)	(0.008)	(0.007)
CASHCOMP	-0.002	0.012	0.012	0.029	0.030	0.025	-0.001	-0.001	-0.002
	(0.019)	(0.013)	(0.011)	(0.019)	(0.019)	(0.019)	(0.013)	(0.013)	(0.020)
TENURE	-0.007	-0.007	-0.005						
	(0.006)	(0.005)	(0.005)						
RD	0.156	0.161	0.172	0.171	0.186	0.176	0.169	0.174	0.183
	(0.187)	(0.159)	(0.158)	(0.134)	(0.145)	(0.130)	(0.146)	(0.138)	(0.149)
CAP	-0.108	-0.118*	-0.107	-0.149**	-0.132**	-0.127*	-0.133**	-0.133**	-0.125*
	(0.082)	(0.071)	(0.071)	(0.061)	(0.061)	(0.071)	(0.064)	(0.061)	(0.072)
LEV	0.006*	0.013***	0.009***	0.011**	0.023***	0.015***	0.037***	0.030***	0.034**
	(0.004)	(0.004)	(0.003)	(0.005)	(0.008)	(0.005)	(0.012)	(0.011)	(0.015)
DIV	-0.012**	-0.10*	-0.013**	-0.012*	-0.013*	-0.008	-0.017**	-0.016*	-0.013*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.005)	(0.008)	(0.008)	(0.008)
Constant	-0.357	0.253	0.320	0.249**	0.266**	0.228**	0.849***	0.754***	0.975***
	(0.592)	(0.322)	(0.285)	(0.112)	(0.131)	(0.113)	(0.133)	(0.115)	(0.152)

In the first stage, the endogenous variables (i.e., *GENDER*, *DELTA·GENDER*, and *DELTA²·GENDER*) are regressed on the instrument (i.e., *GENEQUALITY*, *DELTA·GENEQUALITY*, and *DELTA²·GENEQUALITY*) and predetermined variables. In the second stage, the dependent variable, firm risk taking, is measured as the standard deviation of monthly stock returns over the last five years. See independent variable definitions in Section 4.3.2. L_1, L_2, and L_3 indicate different levels of the CWZ barrier and refer to 1.5, 2 and 2.5 times the exercise price, respectively. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.
*, **, *** Significant at 10%, 5%, and 1%, respectively.

Table 5. Propensity score matching. Influence of the executive's gender and corporate hierarchy on the ESO risk taking effect

	Probit regression	All executives	CEOs	CFOs	Others
	(1)	(2)	(3)	(4)	(5)
DELTA		0.248***	0.291***	0.284***	0.301***
		(0.003)	(0.008)	(0.011)	(0.010)
$DELTA^2$		-0.021***	-0.024***	-0.030***	-0.035***
		(0.001)	(0.001)	(0.003)	(0.002)
DELTA· GENDER		0.135**	0.193	0.169	-0.135
		(0.065)	(0.167)	(0.107)	(0.095)
$DELTA^2$· GENDER		-0.023***	-0.009**	-0.013*	-0.015
		(0.002)	(0.004)	(0.007)	(0.010)
GENDER		-0.531***	-0.835***	-0.633***	-0.551***
		(0.031)	(0.254)	(0.066)	(0.061)
VEGA		0.028**	0.044**	0.022*	0.019**
		(0.012)	(0.018)	(0.012)	(0.009)
CASHCOMP	-0.000				
	(0.000)				
TENURE	-0.254***				
	(0.051)				
RD	-7.694***				
	(1.608)				
LEV	-0.850***				
	(0.319)				
CAP	2.757***				
	(1.007)				
DIV	-0.165**				
	(0.075)				
SIZE	-0.385***				
	(0.032)				
GENEQUALITY	0.045***				
	(0.005)				
Num. Obs.	24604	3046	394	650	2002

The dependent variable in the probit model is the female dummy variable (*GENDER*). Results using the matched sample are presented in columns 2-5. The maximum difference in the propensity score does not exceed 0.1% in absolute value. Firm risk taking is measured as the standard deviation of monthly stock returns over five years. See independent variable definitions in Section 4.3.2. To calculate Deltas and Vegas, we consider a level of the barrier equal to 2 times de exercise price. We use natural logarithmic transformations of Delta and Vega plus 1 to avoid finding the logarithm of zero, that is, ln(1+Delta) and ln(1+Vega). The Hansen test has been used to test endogeneity and the null hypothesis of the validity of the instruments is accepted. Standard errors in parentheses.
*, **, *** Significant at 10%, 5%, and 1%, respectively

Finally, Table 5 presents the last robustness check which refers to the propensity score procedure applied to build the matched-firm samples in which each firm with a female executive is matched with a similar firm with a male executive. Column 1 reports the results of the probit regression. It can be observed that as CEO tenure, research and development expenditure, leverage, diversification and firm size increase, the probability of having female executives decreases, but capital expenditure and the indicator of gender equality developed by Sugarman and Straus (1988) impact positively on this probability. Column 2 is used to test Hypothesis 1 and Columns 3-5 show results for each executive category (Hypothesis 2). To simplify the calculations and extension of Table 5, delta and vega values have been calculated with the middle level of the barrier (L=2). The matched-sample regressions indicate that, considering all executives in the sample, the significant coefficients β_1^* and β_2^* mean that the point of wealth at risk at which female executives start taking less risk is lower than that of their male counterparts, supporting Hypothesis 1. Regarding the three major executive categories considered to test Hypothesis 2, the estimates are broadly consistent with the main analysis. As the position at the top management level decreases, the wealth at risk associated with a change in executive risk taking behavior (from positive to negative) becomes smaller, while there are greater gender differences in the risk taking effect of stock options at the top of the corporate hierarchy.

4.5. CONCLUSIONS

The existing literature focused on incentive-based compensation components has generated important, but contradictory, insights into the role that stock options plays in providing executives with incentives for risk taking. Whether stock options encourage or discourage executive risk taking depends on the theoretical point of view from which previous studies built their hypotheses, the ESO valuation model used, and essential factors that influence the level of executive risk aversion and therefore the risk taking effect created by stock options. In this regard, the evidence seems to confirm the greater risk aversion of female executives compared to their male counterparts, as well as the more risk taking behavior that CEOs typically adopt compared to non-CEO executives.

In this study, using panel data for matched samples of S&P 1500 firms for the fiscal years 2006-2011 and controlling for potential endogeneity issues through different methodologies, we take a step forward in addressing the risk taking effect of option-based compensation. From a theoretical point of view, both agency theory and BAM are necessary to explain the risk behavior of those executives who receive stock options as part of their compensation packages (Martin *et al*., 2013; Baixauli-Soler *et al*., 2014). Then, combining agency and BAM perspectives, we examine if the risk taking effect created by ESOs depends on the gender of the executive and the position held by the executive at the top of the corporate hierarchy.

In particular, we use the sensitive of executive wealth to stock price, or delta, to measure the joint effect or agency theory and BAM, showing the inverted U-shaped relationship between delta and risk taking found by Baixauli-Soler *et al*. (2014). According to the predictions based on this dual perspective, the findings reveal that the non-linear risk taking effect of stock options is affected by the gender of the executive and the executive category. In particular, female executives adopt more conservative behavior than their male counterparts, providing evidence in support of the higher risk aversion among female executives. After the risk-increasing behavior associated with low delta values, female executives exhibit risk-reducing behavior when their wealth at risk is lower than that of male executives, which means that female executives are not willing to bear so much risk as their male counterparts.

On the other hand, regarding the executive category effect, the concave relationship differs significantly when we take into account whether the executive is the CEO of the firm, the CFO, or occupies a lower position. Specifically, controlling for endogeneity, stock options encourage CEOs to adopt riskier behavior than non-CEO executives. As the executive category decreases, the perceived wealth at risk (or risk bearing) of executives increases, and therefore they start taking less risk for lower delta values. Also, the findings indicate that gender differences with respect to the ESO risk taking are significantly present at the level of CEOs and CFOs.

The results are consistent with the recent research line which shows that those executives who are more risk averse are less willing to accept compensation packages with high risk incentives. Female executives are more risk averse than male executives, just as non-CEO executives seem to be more risk averse than CEOs. In each case, more risk averse executives exhibit more conservative behavior when they receive stock options.

This research provides new evidence about the way that top executives respond to risk taking incentives, which is an aspect of considerable importance in those large publicly traded firms in which the separation between ownership and control exists. In addition, because corporate decisions are usually made not only by the CEO, but also by the other executives who are part of the TMT, the analysis presented here looks beyond the CEO to provide a better understanding of the impact of executives' incentives on their risk taking behavior. On the other hand, the use of a model that adapts perfectly to the features of stock option plans makes it possible to capture perfectly the executives' attitude toward risk caused by stock option awards.

In summary, this research helps academics and practitioners gain a deeper understanding of the use of stock options as an incentive tool, filling an important gap in the existing literature. Executives' attitudes to risk play an important role in explaining the effect of ESOs on risk taking, and therefore compensation committees should consider the different levels of risk aversion of their executives, related to gender and executive category, when they design stock option plans.

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CONCLUSIONS

One of the most relevant changes in corporate compensation policies over recent decades is the use of stock options in executive compensation packages. Executive stock options (ESOs) have played an important role in the corporate governance process and the debate about their use as an incentive mechanism is still open. Through both the sensitivity of executive wealth to stock price, or delta, and the sensitivity of executive wealth to stock return volatility, or vega, stock options influence executives' risk preferences. However, in spite of the existence of numerous theoretical and empirical studies, the evidence on how stock options affect executive risk taking is inconclusive. This thesis, therefore, seeks to contribute to this area of research by examining in detail the incentives provided by ESOs, delta and vega, by using appropriate ESO valuation models (Part I). It also contributes to a better understanding of the ESO risk taking effect by combining agency and BAM perspectives and considering the moderating role of TMT gender diversity, the gender of the executive and his or her position in the corporate hierarchy (Part II).

The first chapter presents a sensitivity analysis of the influence of the characteristics of ESOs (the firm's stock price, time to maturity, vesting period, stock return volatility, early exercise and job termination risk) on both executive wealth sensitivities (delta and vega). The aim of this study is to compare deltas and vegas calculated through the classical Black-Scholes (BS) model and the Cvitanic-Wiener-Zapatero (CWZ) model. The findings indicate that research on option-based compensation is not robust to the use of different ESO pricing models. The current corporate practice of calculating the value of ESOs using the BS model is not the more appropriate choice. Valuations resulting from the BS formula are too high because they ignore, for instance, the fact that ESOs are usually exercised early. In addition, BS and CWZ deltas and vegas behave differently when the time to maturity, and therefore the vesting period, is analyzed. By focusing on the specific characteristics of ESOs that are only captured by the CWZ model, the findings highlight the importance of considering the early exercise effect and job termination risk for valuing option incentives properly. The BS model does not capture these important characteristics of ESOs, which leads to the conclusion that

CWZ deltas and vegas are more appropriately used to examine the effects on executive risk-taking behavior. Thus, the second part of this chapter uses the CWZ model to show empirically that those firms which operate in volatile environments compensate their executives with stronger incentives to increase stock price and volatility (higher delta and vega). These results clarify the inconsistency found in the previous literature which may result from the use of inappropriate valuation models.

Among the specific characteristics that many stock option plans may include, the performance-vesting condition has become increasingly common in recent years. In this case, executives can only exercise their options if the firm's stock price reaches a predetermined level. As an extension of the first chapter, the second chapter focuses on this important feature and its influence on option incentives. To do that, this research considers a completely analytical model for valuing performance-vested stock options (PVSOs), the Wu-Lin (WL) model, which captures most of the important characteristics of PVSOs. Incorporating in the WL framework the voluntary early exercise effect, this study presents a sensitivity analysis of the PVSO value and incentives, complementing this analysis with a real case of stock option grants. The findings indicate that as the performance vesting-condition increases and when early exercise is less likely to happen, the PVSO values are lower. Moreover, the increase in the performance-vesting condition is associated with lower delta and higher vega, which may encourage executives to take more risk since the evidence shows that large vegas (deltas) encourage (discourage) risk taking. The results also show that the level of incentives depends on the gap between the performance-vesting condition and the point at which executives exercise their options early, providing evidence in support of the importance of considering voluntary early exercise in the design of performance-vested option plans.

Through CWZ delta values, the third and the fourth chapters combine the arguments of agency theory and BAM to show that the attitude toward risk of those executives who are compensated with stock options is not linear and depends on their wealth at stake. The third chapter focuses on the entire TMT as the unit of analysis because of the importance of all top executives for the conduct of the firm and performance outcomes. The aim is to examine how the TMT responds to ESOs in terms of risk taking. Since considerable empirical evidence shows that female executives are more risk and loss averse than their male counterparts, this research attempts to provide insight into the moderating role of female representation in the TMT. After controlling for potential endogeneity, this chapter shows that there is an inverted U-shaped relationship between the current and prospective wealth created by ESOs for members of the TMT and risk taking. In other words, the TMT adopts risk-increasing behavior (seeking to increase the firm's stock price) up to a certain level of wealth and, from this point on, the TMT exhibits risk-decreasing behavior in order to protect the perceived current wealth. Thus, the evidence confirms that firm risk taking is a combination of the agency and BAM perspectives and their emphasis on prospective and current wealth, respectively. The findings also indicate that those TMTs in which there is female representation exhibit more conservative behavior compared to that of non-gender diverse TMTs. Consistent with the results of the first part of this thesis, all the analyses in this chapter emphasize that deltas and vegas based on the BS model are not appropriate for examining the influence of ESOs on executive risk-taking behavior. Consequently, using the CWZ model, a better picture of the risk taking effect of stock option grants and the moderating role of TMT gender diversity is obtained.

As an extension of the third chapter, the last chapter of this thesis draws on the theoretical combination of agency theory and BAM to examine whether gender differences in risk propensity impact on the individual risk-taking behavior of executives (without focusing on the TMT risk behavior as a group). Moreover, most previous studies have focused on the figure of the CEO to analyze the ESO risk taking effect, and ignore the fact that non-CEO executives may exhibit different risk taking behavior when they receive stock options. In this regard, although executives are risk averse, prior research shows that the CEO is generally more willing to take risks than other TMT members. Consequently, this chapter also examines whether the executive category has an influence on the ESO risk taking effect. Because there are few women at the top management level in S&P 1500 listed firms, analyses have been conducted using matched samples of male and female executives. The findings show that the inverted U-shaped relationship between option incentives and risk taking differs according to the gender of the executive. The maximum delta value at which female executives change from risk-increasing behavior to risk-reducing behavior is lower than that of their male counterparts, providing support for the common assertion of higher female risk aversion. In addition, the results show that the position held in the corporate hierarchy impacts the ESO risk taking effect. Non-CEO executives are more conservative in the risk taking behavior motivated by stock options than CEOs, and gender differences within each executive category are strongest at the level of the CEO.

In summary, it can be concluded that standard methods for valuing exchange-traded options, such as the Black-Scholes model, are not directly applicable to the valuation of ESOs. Firms should adopt specific ESO valuation models to provide executives with appropriate incentives according to the firm's risk-related goals. On the other hand, the findings obtained in this thesis have other important implications for optimal compensation contracts. In relation to the design of stock options with performance-vesting conditions, although the early exercise depends on the executive's personal decision, compensation committees should analyze how their executives behave in terms of exercising their options and, according to this behavior, set suitable performance-vesting conditions.

In addition, the level of firm risk depends on the incentives provided for the firm's key executives, and therefore compensation committees should consider the useful tools provided in this research when designing stock option plans. If the aim of the firm is to undertake some positive net present value projects even though those projects are very risky, compensation committees should adopt more aggressive policies of granting stock options for gender diverse TMTs. In order to avoid the rejection to those risky projects, these stock option plans should provide gender diverse TMTs with stronger incentives to increase the level of firm risk. In the same way, at the individual level, female executives will require stock option plans with higher incentives to increase the firm's risk level. Finally, compensation committees should take into account the fact that the executive category in the corporate hierarchy is associated with different propensities to risk. CEOs seem to be more willing to take risks, and therefore stock option plans with higher incentives to risk taking may lead CEOs to take excessive risk, which may have undesired effects due to an excessive risk propensity. In short, compensation committees should pay closer attention to the differences in willingness to take risks among their executives to compensate them with appropriate stock option incentives which encourage them to act in the best interests of shareholders.

Future research should take a step forward in addressing the risk taking effect of ESOs by taking into account different dimensions related to executives, such as educational background, age and tenure. In addition, due to data availability, this thesis has focused exclusively on executives of large US firms. It would be interesting to extend the current research to a wide sample of firms located in other developed countries to examine whether US executives and their non-US counterparts differ in their risk taking behavior.

Finally, regarding the complicated issue of ESO valuation, other characteristics, such as resetting or reloading, should be taken into account in order to value ESOs and their incentive effects properly. In this way, it would be possible to provide a broad panoramic and deeper understanding of delta and vega and their effects on risk taking. In particular, the CWZ model could be further extended in order to attempt to capture such practices (resetting and reloading) with the aim of designing a more complete model.

APPENDIX

A) ***Cvitanic-Wiener-Zapatero (2008) model***

The option price is:

K11+K12+K2+K3

$$K_{11} = Le^{-\alpha T_0} e^{-(r_{\alpha+\lambda_0})T_0} \left(\frac{L}{s}\right)^{\frac{y_-^\alpha - c_\alpha}{\sigma^2}} e^{\frac{c_\alpha - y_-^\alpha}{\sigma^2}(r_0 - \sigma^2/2)T_0}$$
$$\times B\left(\frac{(c_\alpha - y_-^\alpha)\sqrt{T_0}}{\sigma}, Q, d_0(L) + \frac{\sqrt{T-T_0}}{\sigma} c_\alpha\right)$$
$$- Ke^{-(r_0+\lambda_0)T_0} \left(\frac{L}{s}\right)^{\frac{y_-^\alpha - \bar{c}}{\sigma^2}} e^{\frac{\bar{c} - y_-^\alpha}{\sigma^2}(r_0 - \sigma^2/2)T_0}$$
$$\times B\left(\frac{(\bar{c} - y_-^\alpha)\sqrt{T_0}}{\sigma}, Q, d_0(L) + \frac{\sqrt{T-T_0}}{\sigma} \bar{c}\right)$$
$$+ Le^{-\alpha T_0} e^{-(r_0+\lambda_0)T_0} \left(\frac{L}{s}\right)^{\frac{y_-^\alpha + c_\alpha}{\sigma^2}} e^{-\frac{c_\alpha + y_-^\alpha}{\sigma^2}(r_0 - \sigma^2/2)T_0}$$
$$\times B\left(-\frac{(c_\alpha + y_-^\alpha)\sqrt{T_0}}{\sigma}, Q, d_0(L) - \frac{\sqrt{T-T_0}}{\sigma} c_\alpha\right)$$
$$- Ke^{-(r_0+\lambda_0)T_0} \left(\frac{L}{s}\right)^{\frac{y_-^\alpha + \bar{c}}{\sigma^2}} e^{-\frac{\bar{c} + y_-^\alpha}{\sigma^2}(r_0 - \sigma^2/2)T_0}$$
$$\times B\left(-\frac{(\bar{c} + y_-^\alpha)\sqrt{T_0}}{\sigma}, Q, d_0(L) - \frac{\sqrt{T-T_0}}{\sigma} \bar{c}\right).$$

$$K_{12} = e^{(\lambda-\lambda_0)T_0} e^{-\lambda T_0} \left[sN\left(\frac{\sqrt{T_0}}{\sigma}\left(r_0 + \frac{\sigma^2}{2}\right) + \frac{\log(s/L)}{\sigma\sqrt{T_0}}\right)\right.$$
$$\left. - Ke^{-r_0 T_0} N\left(\frac{\sqrt{T_0}}{\sigma}\left(r_0 - \frac{\sigma^2}{2}\right) + \frac{\log(s/L)}{\sigma\sqrt{T_0}}\right)\right].$$

$$\begin{aligned}K_2 = e^{(\lambda-\lambda_0)T_0} e^{-(r_0+\lambda)T_0} \Big[& D_1(K, r_0, r_0, b_0) + D_2(K, r_0, r_0, c_0) \\ & - D_1(L, r_0, r_\alpha, b_\alpha) - \frac{K}{L} D_2(L, r_0, r_\alpha, \bar{c}) - G_1(K, r_0, r_0, b_0) \\ & - G_2(K, r_0, r_0, c_0) + G_1(L, r_0, r_\alpha, b_\alpha) + \frac{K}{L} G_2(L, r_0, r_\alpha, \bar{c}) \Big].\end{aligned}$$

$$\begin{aligned}K_3 = e^{(\lambda-\lambda_0)T_0} e^{-\lambda T - r_0 T_0} \big[& C_0(K_\alpha(T - T_0)) \\ & - C_0(L) - C_1(K_\alpha(T - T_0)) + C_1(L) \big].\end{aligned}$$

Where,

$$K_\alpha(T) = Ke^{-\alpha T}, \; r_\alpha = r_0 - \alpha;$$

$$X_Y = \frac{\log(Y/s)}{\sigma\sqrt{T_0}} - (r_0 - \sigma^2/2)\frac{\sqrt{T_0}}{\sigma};$$

$$y_+^\alpha = r_\alpha + \frac{\sigma^2}{2}, \; y_-^\alpha = r_\alpha - \frac{\sigma^2}{2}, \; \bar{y} = \sqrt{(y_-^\alpha)^2 + 2\sigma^2 r_0};$$

$$\tilde{K}_\alpha(T) = \log(s/K_\alpha(T)), \; \tilde{L} = \log(s/L);$$

$$b_\alpha := \sqrt{(r_\alpha + \sigma^2/2)^2 + 2\sigma^2\lambda};$$

$$c_\alpha := \sqrt{(r_\alpha - \sigma^2/2)^2 + 2\sigma^2(\lambda + r_\alpha)}, \; \bar{c} := \sqrt{(r_\alpha - \sigma^2/2)^2 + 2\sigma^2(\lambda + r_0)}.$$

$$
\begin{aligned}
P_1^{\alpha}(s) = {} & sN\left(\frac{\tilde{K}_{\alpha}(T)}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} + \frac{\sigma_2}{2}\right)\right) \\
& - K_{\alpha}(T)e^{-r\alpha T}N\left(\frac{\tilde{K}_{\alpha}(T)}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} - \frac{\sigma_2}{2}\right)\right) \\
& - sN\left(\frac{\tilde{L}}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} + \frac{\sigma_2}{2}\right)\right) \\
& + K_{\alpha}(T)e^{-r\alpha T}N\left(\frac{\tilde{L}}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} - \frac{\sigma_2}{2}\right)\right) \\
& - \left(\frac{L}{s}\right)^{\frac{2r_{\alpha}}{\sigma^2}-1}\left[\frac{L^2}{s}N\left(\frac{1}{\sigma\sqrt{T}}log\left(\frac{L^2}{sK_{\alpha}(T)}\right) + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} + \frac{\sigma^2}{2}\right)\right)\right. \\
& - K_{\alpha}(T)e^{-r_{\alpha}T}N\left(\frac{1}{\sigma\sqrt{T}}log\left(\frac{L^2}{sK_{\alpha}(T)}\right) + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} - \frac{\sigma^2}{2}\right)\right) \\
& - \frac{L^2}{s}N\left(-\frac{\tilde{L}}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} + \frac{\sigma^2}{2}\right)\right) \\
& \left. + K_{\alpha}(T)e^{-r\alpha T}N\left(-\frac{\tilde{L}}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}\left(r_{\alpha} - \frac{\sigma_2}{2}\right)\right)\right].
\end{aligned}
$$

$$
\begin{aligned}
P(s,T,\mu,y) = {} & \left(\frac{L}{s}\right)^{\frac{\mu-y}{\sigma^2}} N\left(\frac{\log(s/L)}{\sigma\sqrt{T}} + \frac{\sqrt{T}}{\sigma}y\right) \\
& + \left(\frac{L}{s}\right)^{\frac{\mu+y}{\sigma^2}} N\left(\frac{\log(s/L)}{\sigma\sqrt{T}} - \frac{\sqrt{T}}{\sigma}y\right).
\end{aligned}
$$

$$
\begin{aligned}
&I_1(x,T,z,r,b)\\
&= x\left[1_{\{x>z\}}+\frac{1}{2}1_{\{x=z\}}-e^{-\lambda T}N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}\left(r+\sigma^2/2\right)\right)\right]\\
&+x\left(\frac{z}{x}\right)^{\frac{r-b}{\sigma^2}+\frac{1}{2}}\left\{\frac{r+\sigma^2/2}{b}\left[N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}b\right)-1_{\{x>z\}}-\frac{1}{2}1_{\{x=z\}}\right]\right.\\
&+\frac{1}{2}\left[1-\frac{r+\sigma^2/2}{b}\right]\left[N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}b\right)\right.\\
&\left.\left.+\left(\frac{z}{x}\right)^{\frac{2b}{\sigma^2}}N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}-\frac{\sqrt{T}}{\sigma}b\right)-\left[1+\left(\frac{z}{x}\right)^{\frac{2b}{\sigma^2}}\right]1_{\{x>z\}}-1_{\{x=z\}}\right]\right\}.
\end{aligned}
$$

$$
\begin{aligned}
&I_2(x,T,z,R,r,c)\\
&=-\frac{\lambda_z}{\lambda+R}\left[1_{\{x>z\}}+\frac{1}{2}1_{\{x=z\}}-e^{-(\lambda+R)T}N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}\left(r-\sigma^2/2\right)\right)\right]\\
&-\frac{\lambda_z}{\lambda+R}\left(\frac{z}{x}\right)^{\frac{r-c}{\sigma^2}-\frac{1}{2}}\left\{\frac{r-\sigma^2/2}{c}\left[N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}c\right)\right.\right.\\
&\left.-1_{\{x>z\}}-\frac{1}{2}1_{\{x=z\}}\right]+\frac{1}{2}\left[1-\frac{r-\sigma^2/2}{c}\right]\left[N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}+\frac{\sqrt{T}}{\sigma}c\right)\right.\\
&\left.\left.+\left(\frac{z}{x}\right)^{\frac{2c}{\sigma^2}}N\left(\frac{\log(x/z)}{\sigma\sqrt{T}}-\frac{\sqrt{T}}{\sigma}b\right)-\left[1+\left(\frac{z}{x}\right)^{\frac{2c}{\sigma^2}}\right]1_{\{x>z\}}-1_{\{x=z\}}\right]\right\}.
\end{aligned}
$$

$$
B(a,b,c):=\int_{-\infty}^{x_L}e^{ax}N(bx+c)n(x)dx=e^{\frac{a^2}{2}}P(X\le x_L,Y\le c)
$$

where (X,Y) has a bivariate normal distribution with

$$\mu_X = a,\ \mu_Y = -ab,\ \sigma_X^2 = 1,\ \sigma_Y^2 = 1 + b^2,\ \rho = -\frac{b}{\sqrt{1+b^2}}$$

$$Q = \sqrt{\frac{T_0}{T - T_0}}.$$

$$d_0(Y) = \frac{1}{\sigma\sqrt{T - T_0}}\left[\log(s/Y) + \left(r_0 - \sigma^2/2\right)T_0\right].$$

$$d_1(Y) = \frac{1}{\sigma\sqrt{T - T_0}}\left[\log\left(\frac{L^2}{sY}\right) - \left(r_0 - \sigma^2/2\right)T_0\right].$$

$$C_0(Y) = se^{\left(r_0 - \sigma^2/2\right)T_0} B\left(\sigma\sqrt{T_0}, Q, d_0(Y) + \frac{\sqrt{T - T_0}}{\sigma}\left(r_\alpha + \sigma^2/2\right)\right)$$
$$- Ke^{-\alpha(T - T_0)} e^{-r_\alpha(T - T_0)} B\left(0, Q, d_0(Y) + \frac{\sqrt{T - T_0}}{\sigma}\left(r_\alpha - \sigma^2/2\right)\right).$$

$$C_1(X) = L\left(\frac{L}{S}\right)^{\frac{2r_\alpha}{\sigma^2}} e^{-\frac{2r_\alpha}{\sigma^2}\left(r_0 - \sigma^2/2\right)T_0} B\left(-\frac{2r_\alpha}{\sigma}\sqrt{T_0}, -Q, -d_0\left(L^2/X\right)\right.$$
$$\left. + \frac{\sqrt{T - T_0}}{\sigma}\left(r_\alpha + \sigma^2/2\right)\right) - Ke^{-\alpha(T - T_0)}\left(\frac{L}{s}\right)^{\frac{2r_\alpha}{\sigma^2} - 1}$$
$$\times e^{-r_\alpha(T - T_0) - \left(\frac{2r_\alpha}{\sigma^2} - 1\right)\left(r_0 - \sigma^2/2\right)T_0} B\left(\frac{\sigma_2 - 2r_\alpha}{\sigma}\sqrt{T_0}, -Q, -d_0\left(L^2/X\right)\right.$$
$$\left. + \frac{\sqrt{T - T_0}}{\sigma} y_-^\alpha\right).$$

$$
\begin{aligned}
D_1(Y,R,r,b) &= \int_{-\infty}^{x_L} I_1\left(p(T_0,s,x),T-T_0,Y,r,b\right)n(x)dx \\
&= -se^{\left(R-\sigma^2/2\right)T_0-\lambda(T-T_0)}B\left(\sigma\sqrt{T_0},Q,d_0(Y)+\left(r+\sigma^2/2\right)\frac{\sqrt{T-T_0}}{\sigma}\right) \\
&+\frac{1}{2}\left[1+\frac{1}{b}\left(r+\sigma^2/2\right)\right]s\left(\frac{Y}{s}\right)^{\frac{r-b}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{b-r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0} \\
&\times B\left(\left[\frac{b-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0},Q,d_0(Y)+b\frac{\sqrt{T-T_0}}{\sigma}\right) \\
&+\frac{1}{2}\left[1-\frac{1}{b}\left(r+\sigma^2/2\right)\right]s\left(\frac{Y}{s}\right)^{\frac{r+b}{\sigma^2}+\frac{1}{2}}e^{\left[-\frac{b+r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0} \\
&\times B\left(\left[-\frac{b+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0},Q,d_0(Y)-b\frac{\sqrt{T-T_0}}{\sigma}\right) \\
&+se^{RT_0}\left[N\left(x_L-\sigma\sqrt{T_0}\right)-N\left(x_Y-\sigma\sqrt{T_0}\right)\right] \\
&-\frac{1}{2}\left[1+\frac{1}{b}\left(r+\sigma^2/2\right)\right]s\left(\frac{Y}{s}\right)^{\frac{r-b}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{b-r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{b-r}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0} \\
&\times\left[N\left(x_L-\left[\frac{b-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)-N\left(x_Y-\left[\frac{b-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)\right] \\
&-\frac{1}{2}\left[1-\frac{1}{b}\left(r+\sigma^2/2\right)\right]s\left(\frac{Y}{s}\right)^{\frac{r+b}{\sigma^2}+\frac{1}{2}}e^{\left[-\frac{b+r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[-\frac{b+r}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0} \\
&\times\left[N\left(x_L-\left[-\frac{b+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)-N\left(x_Y-\left[-\frac{b+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)\right].
\end{aligned}
$$

$$
\begin{aligned}
D_2(Y,R,r,c) &= \int_{-\infty}^{x_L} I_2\left(p(T_0,s,x),T-T_0,Y,R,r,c\right)n(x)dx \\
&= \frac{\lambda Y}{\lambda+R}\left\{e^{-(\lambda+R)(T-T_0)}B\left(0,Q,d_0(Y)+\left(r-\sigma^2/2\right)\frac{\sqrt{T-T_0}}{\sigma}\right)\right. \\
&\quad -\frac{1}{2}\left[1+\frac{1}{c}\left(r-\sigma^2/2\right)\right]\left(\frac{Y}{s}\right)^{\frac{r-c}{\sigma^2}-\frac{1}{2}} e^{\left[\frac{c-r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0} \\
&\quad \times B\left(\left[\frac{c-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0},Q,d_0(Y)+c\frac{\sqrt{T-T_0}}{\sigma}\right) \\
&\quad -\frac{1}{2}\left[1-\frac{1}{c}\left(r-\sigma^2/2\right)\right]\left(\frac{Y}{s}\right)^{\frac{r+c}{\sigma^2}-\frac{1}{2}} e^{\left[-\frac{c+r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0} \\
&\quad \times B\left(\left[-\frac{c+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0},Q,d_0(Y)-c\frac{\sqrt{T-T_0}}{\sigma}\right) \\
&\quad -\left[N(x_L)-N(x_Y)\right] \\
&\quad +\frac{1}{2}\left[1+\frac{1}{c}\left(r-\sigma^2/2\right)\right]\left(\frac{Y}{s}\right)^{\frac{r-c}{\sigma^2}-\frac{1}{2}} e^{\left[\frac{c-r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{c-r}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0} \\
&\quad \times\left[N\left(x_L-\left[\frac{c-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)-N\left(x_Y-\left[\frac{c-r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)\right] \\
&\quad +\frac{1}{2}\left[1-\frac{1}{c}\left(r-\sigma^2/2\right)\right]\left(\frac{Y}{s}\right)^{\frac{r+c}{\sigma^2}-\frac{1}{2}} e^{\left[-\frac{c+r}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[-\frac{c+r}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0} \\
&\quad \left.\times\left[N\left(x_L-\left[-\frac{c+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)-N\left(x_Y-\left[-\frac{c+r}{\sigma}+\frac{\sigma}{2}\right]\sqrt{T_0}\right)\right]\right..
\end{aligned}
$$

$$
\begin{aligned}
&G_1(Y,R,r,b)\\
&=\int_{-\infty}^{x_L}\left(\frac{L}{p(T_0,s,x)}\right)^{\frac{2r_\alpha}{\sigma^2}-1} I_1\left(L^2/p(T_0,s,x),T-T_0,Y,r,b\right)n(x)dx\\
&=-L\left(\frac{L}{s}\right)^{\frac{2r_\alpha}{\sigma^2}} e^{-\frac{2r_\alpha}{\sigma^2}\left(R-\sigma^2/2\right)T_0-\lambda(T-T_0)}\\
&\times B\left(-\frac{2r_\alpha}{\sigma}\sqrt{T_0},-Q,d_1(Y)+\left(r+\sigma^2/2\right)\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&+\frac{L^{\frac{2(r_\alpha+b-r)}{\sigma}}}{2}\left[1+\frac{1}{b}\left(r+\sigma^2/2\right)\right]Y^{\frac{r-b}{\sigma^2}+\frac{1}{2}}s^{\frac{r-b-2r_\alpha}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{1}{2}+\frac{r-b-2r_\alpha}{\sigma^2}\right]\left(R-\sigma^2/2\right)T_0}\\
&\times B\left(\left[\frac{\sigma}{2}+\frac{r-b-2r_\alpha}{\sigma^2}\right]\sqrt{T_0},-Q,d_1(Y)+b\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&+\frac{L^{\frac{2(r_\alpha-b-r)}{\sigma^2}}}{2}\left[1-\frac{1}{b}\left(r+\sigma^2/2\right)\right]Y^{\frac{r+b}{\sigma^2}+\frac{1}{2}}s^{\frac{r+b-2r_\alpha}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{r+b-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0}\\
&\times B\left(\left[\frac{r+b-2r_\alpha}{\sigma^2}+\frac{\sigma}{2}\right]\sqrt{T_0},-Q,d_1(Y)-b\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&+L\left(\frac{L}{s}\right)^{\frac{2r_\alpha}{\sigma^2}} e^{-\frac{2r_\alpha}{\sigma^2}\left(R-\sigma^2/2\right)T_0+\frac{2r_\alpha}{\sigma^2}T_0} N\left(x_{min\left[L,L^2/Y\right]}+\frac{2r_\alpha}{\sigma}\sqrt{T_0}\right)\\
&-\frac{L^{\frac{2(r_\alpha+b-r)}{\sigma^2}}}{2}\left[1+\frac{1}{b}\left(r+\sigma^2/2\right)\right]Y^{\frac{r-b}{\sigma^2}+\frac{1}{2}}s^{\frac{r-b-2r_\alpha}{\sigma^2}+\frac{1}{2}}\\
&\times e^{\left[\frac{1}{2}+\frac{r-b-2r_\alpha}{\sigma^2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{1}{2}+\frac{r-b-2r_\alpha}{\sigma^2}\right]^2\frac{\sigma^2}{2}T_0}\\
&\times N\left(x_{min\left[L,L^2/Y\right]}-\left[\frac{\sigma}{2}+\frac{r-b-2r_\alpha}{\sigma^2}\right]\sqrt{T_0}\right)\\
&-\frac{L^{\frac{2(r_\alpha-b-r)}{\sigma^2}}}{2}\left[1-\frac{1}{b}\left(r+\sigma^2/2\right)\right]Y^{\frac{r+b}{\sigma^2}+\frac{1}{2}}s^{\frac{r+b-2r_\alpha}{\sigma^2}+\frac{1}{2}}\\
&\times e^{\left[\frac{r+b-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{r+b-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0}\\
&\times N\left(x_{min\left[L,L^2/Y\right]}-\left[\frac{\sigma}{2}+\frac{r+b-2r_\alpha}{\sigma^2}\right]\sqrt{T_0}\right).
\end{aligned}
$$

$$
\begin{aligned}
&G_2(Y,R,r,c)\\
&=\int_{-\infty}^{x_L}\left(\frac{L}{p(T_0,s,x)}\right)^{\frac{2r_\alpha}{\sigma^2}-1} I_2\left(L^2/p(T_0,s,x),T-T_0,Y,R,r,c\right)n(x)dx\\
&=\frac{\lambda Y}{\lambda+R}\left\{\left(\frac{L}{s}\right)^{\frac{2r_\alpha}{\sigma^2}-1} e^{\left(1-\frac{2r_\alpha}{\sigma^2}\right)\left(R-\sigma^2/2\right)T_0-(\lambda+R)(T-T_0)}\right.\\
&\times B\left(\left(\sigma-\frac{2r_\alpha}{2}\right)\sqrt{T_0},-Q,d_1(Y)+\left(r-\sigma^2/2\right)\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&-\frac{L^{\frac{2(r_\alpha+c-r)}{\sigma^2}}}{2}\left[1+\frac{1}{c}\left(r-\sigma^2/2\right)\right]Y^{\frac{r-c}{\sigma^2}-\frac{1}{2}}s^{\frac{r-c-2r_\alpha}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{1}{2}+\frac{r-c-2r_\alpha}{\sigma^2}\right]\left(R-\sigma^2/2\right)T_0}\\
&\times B\left(\left[\frac{\sigma}{2}+\frac{r-c-2r_\alpha}{\sigma^2}\right]\sqrt{T_0},-Q,d_1(Y)+c\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&-\frac{L^{\frac{2(r_\alpha-c-r)}{\sigma^2}}}{2}\left[1-\frac{1}{c}\left(r-\sigma^2/2\right)\right]Y^{\frac{r+c}{\sigma^2}-\frac{1}{2}}s^{\frac{r+c-2r_\alpha}{\sigma^2}+\frac{1}{2}}e^{\left[\frac{r+c-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0}\\
&\times B\left(\left[\frac{r+c-2r_\alpha}{\sigma^2}+\frac{\sigma}{2}\right]\sqrt{T_0},-Q,d_1(Y)-c\frac{\sqrt{T-T_0}}{\sigma}\right)\\
&-\left(\frac{L}{s}\right)^{\frac{2r_\alpha}{\sigma^2}-1} e^{\left(1-\frac{2r_\alpha}{\sigma^2}\right)\left(R-\sigma^2/2\right)T_0+\left(1-\frac{2r_\alpha}{\sigma^2}\right)^2\frac{\sigma^2}{2}T_0} N\left(x_{\min\left[L,L^2/Y\right]}\right.\\
&\left.-\left(\sigma-2r_\alpha/\sigma\right)\sqrt{T_0}\right)+\frac{L^{\frac{2(r_\alpha+c-r)}{\sigma^2}}}{2}\left[1+\frac{1}{c}\left(r-\sigma^2/2\right)\right]Y^{\frac{r-c}{\sigma^2}-\frac{1}{2}}s^{\frac{r-c-2r_\alpha}{\sigma^2}+\frac{1}{2}}\\
&\times e^{\left[\frac{1}{2}+\frac{r-c-2r_\alpha}{\sigma^2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{1}{2}+\frac{r-c-2r_\alpha}{\sigma^2}\right]^2\frac{\sigma^2}{2}T_0}\\
&\times N\left(x_{\min\left[L,L^2/Y\right]}-\left[\frac{\sigma}{2}+\frac{r-c-2r_\alpha}{\sigma^2}\right]\sqrt{T_0}\right)\\
&+\frac{L^{\frac{2(r_\alpha-c-r)}{\sigma^2}}}{2}\left[1-\frac{1}{c}\left(r-\sigma^2/2\right)\right]Y^{\frac{r+c}{\sigma^2}-\frac{1}{2}}s^{\frac{r+c-2r_\alpha}{\sigma^2}+\frac{1}{2}}\\
&\times e^{\left[\frac{r+c-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]\left(R-\sigma^2/2\right)T_0+\left[\frac{r+c-2r_\alpha}{\sigma^2}+\frac{1}{2}\right]^2\frac{\sigma^2}{2}T_0}\\
&\left.\times N\left(x_{\min\left[L,L^2/Y\right]}-\left[\frac{\sigma}{2}+\frac{r+c-2r_\alpha}{\sigma^2}\right]\sqrt{T_0}\right)\right\}.
\end{aligned}
$$

B) ***Wu-Lin (2013) model***

The option price is:

K_1+K_2

$$K_1 = e^{(\lambda-\lambda_0)T_0} \cdot \left[I_1 + I_2 - I_3 - I_4 - I_5 + I_6\right].$$

$$K_2 = Se^{(\lambda-\lambda_0)T_0-\lambda T} \cdot \left\{ N\left(\frac{ln\left(\frac{S}{B}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) + \left(\frac{B}{S}\right)^{\frac{2\left(r+\frac{\sigma^2}{2}\right)}{\sigma^2}} \right.$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) \right] \right\}$$

$$- Ke^{(\lambda-\lambda_0)T_0-(r+\lambda)T} \cdot \left\{ N\left(\frac{ln\left(\frac{S}{B}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) + \left(\frac{B}{S}\right)^{\frac{2\left(r-\frac{\sigma^2}{2}\right)}{\sigma^2}} \right.$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) \right] \right\}.$$

Where,

$$I_1 = S \cdot \left[e^{-\lambda T_0} N\left(\frac{ln\left(\frac{S}{B}\right) + \left(r + \frac{\sigma^2}{2}\right) T_0}{\sigma\sqrt{T_0}} \right) - e^{-\lambda T} N\left(\frac{ln\left(\frac{S}{B}\right) + \left(r + \frac{\sigma^2}{2}\right) T}{\sigma\sqrt{T}} \right) + I_{11} \right].$$

$$I_{11} = \left(\frac{B}{S}\right)^{\frac{r - \sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma^2} + \frac{1}{2}} \times \left\{ \left[\frac{1}{2}\left(1 + \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \right.$$

$$\times \left[N\left(\frac{ln\left(\frac{S}{B}\right) + T\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) + T_0\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right]$$

$$+ \left[\frac{1}{2}\left(1 - \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \left(\frac{B}{S}\right)^{\frac{2\sqrt{\left(r + \frac{\sigma^2}{2}\right) + 2\sigma^2\lambda}}{\sigma^2}}$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{S}{B}\right) - T\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) - T_0\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right] \right\}.$$

$$I_2 = S\left(\frac{B}{S}\right)^{\frac{2\left(r+\frac{\sigma^2}{2}\right)}{\sigma^2}} \cdot \left\{ e^{-\lambda T_0} N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r + \frac{\sigma^2}{2}\right) T_0}{\sigma\sqrt{T_0}} \right) - e^{-\lambda T} N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r + \frac{\sigma^2}{2}\right) T}{\sigma\sqrt{T}} \right) + I_{21} \right\}.$$

$$I_{21} = \left(\frac{S}{B}\right)^{\frac{r+\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2\lambda}}{\sigma^2}+\frac{1}{2}} \times \left\{ \left[\frac{1}{2}\left(1 - \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \right.$$

$$\times \left[N\left(\frac{ln\left(\frac{S}{B}\right) + T\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) + T_0\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right]$$

$$+ \left[\frac{1}{2}\left(1 + \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \left(\frac{B}{S}\right)^{\frac{2\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2+2\sigma^2\lambda}}{\sigma^2}}$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{S}{B}\right) - T\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) - T_0\sqrt{\left(r + \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right] \right\}.$$

$$I_3 = S\left(\frac{B}{S}\right)^{\frac{2\left(r+\frac{\sigma^2}{2}\right)}{\sigma^2}} \cdot \left\{ e^{-\lambda T_0} N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r + \frac{\sigma^2}{2}\right)T_0}{\sigma\sqrt{T_0}} \right) - e^{-\lambda T} N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) + I_{31} \right\}.$$

$$I_{31} = \left(\frac{SK}{B^2}\right)^{\frac{r+\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2+2\sigma^2\lambda}}{\sigma^2}+\frac{1}{2}} \times \left\{ \left[\frac{1}{2}\left(1 - \frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \right.$$

$$\times \left[N\left(\frac{ln\left(\frac{SK}{B^2}\right) + T\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) + T_0\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right]$$

$$+ \left[\frac{1}{2}\left(1 + \frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}} \right) \right] \left(\frac{B^2}{SK}\right)^{\frac{2\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2+2\sigma^2\lambda}}{\sigma^2}}$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{SK}{B^2}\right) - T\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) - T_0\sqrt{\left(r+\frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda}}{\sigma\sqrt{T_0}} \right) \right] \right\}.$$

$$I_4=\frac{\lambda K}{\lambda+r}\cdot\left\{e^{-(\lambda+r)T_0}N\left(\frac{ln\left(\frac{S}{B}\right)+\left(r-\frac{\sigma^2}{2}\right)T_0}{\sigma\sqrt{T_0}}\right)-e^{-(\lambda+r)T}N\left(\frac{ln\left(\frac{S}{B}\right)+\left(r-\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}\right)+I_{41}\right\}.$$

$$\begin{aligned}I_{41}=&\left(\frac{B}{S}\right)^{\frac{r-\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma^2}-\frac{1}{2}}\times\left\{\left[\frac{1}{2}\left(1+\frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}\right)\right]\right.\\
&\times\left[N\left(\frac{ln\left(\frac{S}{B}\right)+T\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T}}\right)-N\left(\frac{ln\left(\frac{S}{B}\right)+T_0\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T_0}}\right)\right]\\
&+\left[\frac{1}{2}\left(1-\frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}\right)\right]\left(\frac{B}{S}\right)^{\frac{2\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma^2}}\\
&\left.\times\left[N\left(\frac{ln\left(\frac{S}{B}\right)-T\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T}}\right)-N\left(\frac{ln\left(\frac{S}{B}\right)-T_0\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T_0}}\right)\right]\right\}.\end{aligned}$$

$$I_5 = \frac{\lambda K}{\lambda + r} \cdot \left(\frac{B}{S}\right)^{\frac{2\left(r - \frac{\sigma^2}{2}\right)}{\sigma^2}} \cdot \left\{ e^{-(\lambda+r)T_0} N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r - \frac{\sigma^2}{2}\right)T_0}{\sigma\sqrt{T_0}} \right) \right.$$

$$\left. - e^{-(\lambda+r)T} N\left(\frac{ln\left(\frac{S}{B}\right) - \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) + I_{51} \right\}.$$

$$I_{51} = \left(\frac{S}{B}\right)^{\frac{r + \sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma^2} - \frac{1}{2}} \times \left\{ \left[\frac{1}{2} \left(1 - \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}} \right) \right] \right.$$

$$\times \left[N\left(\frac{ln\left(\frac{S}{B}\right) + T\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) + T_0\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma\sqrt{T_0}} \right) \right]$$

$$+ \left[\frac{1}{2} \left(1 + \frac{r + \frac{\sigma^2}{2}}{\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}} \right) \right] \left(\frac{B}{S}\right)^{\frac{2\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma^2}}$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{S}{B}\right) - T\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{S}{B}\right) - T_0\sqrt{\left(r - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda + r)}}{\sigma\sqrt{T_0}} \right) \right] \right\}.$$

$$I_6 = \frac{\lambda K}{\lambda + r} \cdot \left(\frac{B}{S}\right)^{\frac{2\left(r-\frac{\sigma^2}{2}\right)}{\sigma^2}} \cdot \left\{ e^{-(\lambda+r)T_0} N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r - \frac{\sigma^2}{2}\right)T_0}{\sigma\sqrt{T_0}} \right) \right.$$

$$\left. - e^{-(\lambda+r)T} N\left(\frac{ln\left(\frac{SK}{B^2}\right) - \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \right) + I_{61} \right\}.$$

$$I_{61} = \left(\frac{SK}{B^2}\right)^{\frac{r+\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma^2}-\frac{1}{2}} \times \left\{ \left[\frac{1}{2}\left(1 - \frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}} \right) \right] \right.$$

$$\times \left[N\left(\frac{ln\left(\frac{SK}{B^2}\right) + T\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) + T_0\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T_0}} \right) \right]$$

$$+ \left[\frac{1}{2}\left(1 + \frac{r+\frac{\sigma^2}{2}}{\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}} \right) \right] \left(\frac{B^2}{SK}\right)^{\frac{2\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma^2}}$$

$$\left. \times \left[N\left(\frac{ln\left(\frac{SK}{B^2}\right) - T\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T}} \right) - N\left(\frac{ln\left(\frac{SK}{B^2}\right) - T_0\sqrt{\left(r-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda+r)}}{\sigma\sqrt{T_0}} \right) \right] \right\}.$$