ESSAYS IN APPLIED ECONOMIC THEORY

by

SADETTİN HALUK ÇİTÇİ

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ESSAYS IN APPLIED ECONOMIC THEORY

APPROVED BY:

Asst. Prof. Remzi Kaygusuz ....
(Dissertation Supervisor)

Asst. Prof. Eren İnci ....
(Dissertation Co-Supervisor)

Asst. Prof. Fırat İnceoğlu ....

Prof. Dr. Mehmet Baç ....

Asst. Prof. Şerif Aziz Şimşir ....

DATE OF APPROVAL:

ABSTRACT

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Sadettin Haluk Çitçi

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Supervisor: Asst. Prof. Eren İnci and Asst. Prof. Remzi Kaygusuz

Keywords Polygyny, Monogamy, Development, Career Concern, Risk Taking

This dissertation consists of two chapters that are independent of each other. Each of them represents an area of my research interests. The first chapter contributes to the fascinating and growing literature of Family Macroeconomics. In this chapter, we offer a simple theory that explains why polygyny marriage has almost disappeared in modern industrialized countries although it had been common in most of the societies throughout history. We demonstrate that the increase in labor income through the process of economic development has led to the rise of monogamy. Specifically, we show in a general equilibrium model of marriage market that the increase in labor income improves women's outside option, monogamy mating. This, in turn, reduces polygyny by increasing the cost of polygyny mating for men. The second chapter is a joint work with Eren Inci and it contributes to the financial economics and career concerns literatures. In particular, we analyze how CEOs' layoff risk affects their risk choice in overseeing the firm. We provide a novel mechanism in which CEOs can change market's belief about their ability by their risk choice. We show that a CEO can decrease her layoff risk by taking excessive risk and trade off current compensation for layoff risk. We allow for any linear combination of fixed-wage and stock compensation and show that there are market structures in which explicit incentives are not helpful in preventing CEOs from taking excessive risk.

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ÖZET

ESSAYS IN APPLIED ECONOMIC THEORY

Sadettin Haluk Çitçi

Doktor, Ekonomi, Bahar 2012

Danışman: Yrd. Doçent Eren İnci ve Yrd. Doçent Remzi Kaygusuz

Anahtar Kelimeler Tek Eşli Evlilik, Çok Eşli Evlilik, Kalkınma, Kariyer Kaygısı, Risk Alma

Bu tez birbirinden bağımsız iki konuyu içermektedir. Bunlardan herbiri ilgilendiğim araştırma alanlarını temsil etmektedir. Tezin ilk bölümü etkileyici ve büyüyen Aile Makroekonomisi literatürüne katkı yapmaktadır. Bu bölümde, çok eşli evliliğin tarih boyunca birçok toplumda yaygın olmasına rağmen neden modern gelişmiş ülkelerde neredeyse kaybolduğunu açıklayan bir kuram öneriyoruz. Ekonomik kalkınma sürecinde iş piyasasındaki ücret seviyesinin artmasının tek eşli evliliğin yükselişine neden olduğunu gösteriyoruz. Özellikle, bir evlilik pazarı genel denge modeli kapsamında, iş piyasasındaki ücret seviyesinin artmasının kadınlar için tek eşli evliliğin değerini arttırdığını, bunun da erkekler için çok eşli evliliğin maliyetini yükseltmek suretiyle çok eşliliği azaltığını gösteriyoruz. Tezin ikinci bölümü ise Eren İnci ile birlikte yazılmış olup, finansal ekonomi ve kariyer kaygısı literatürlerine katkı yapmaktadır. İkinci bölümde, özellikle, CEO'ların işten atılma risklerinin firmayı yönetirken seçtikleri risk seviyesine etkisini analiz ediyoruz. CEO'ların risk seçimleri vasıtasıyla piyasanın onların yönetim kabiliyetleri hakkındaki kanaatlerini değiştirebilceğini gösteren özgün bir mekanizma sunuyoruz. CEO'ların aşırı risk alarak, işten atılma risklerini azaltabildiklerini ve bugün daha az ücret almak pahasına yarın karşı karşıya kalacakları işten atılma riskini azaltmaya çalıştıklarını gösteriyoruz. Modelde, sabit ücret ve şirket hissesi cinsinden ödemelerin her türlü doğrusal karışımına izin veriyor ve teşviklerin CEO'ların aşırı risk almasını önleyemeyebileceği pazar yapılarının olduğunu gösteriyoruz.

To my family...

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CHAPTER 1

THE RISE OF MONOGAMY

1.1 Introduction

Polygynous mating is a global phenomenon in the sense that it has occurred in most of the societies throughout history. For example, Murdock's Ethnographic Atlas mentions that polygyny exists in 850 of the 1,170 societies although its degree varies among them (Hartung, 1982). Similarly, Human Area files documents that 93% of 1154 recorded societies recognize some degree of polygyny (Clark, 1998). Moreover, polygyny is not an issue of the past. We still observe polygynous marriage up to 55% in many countries. On the other hand, polygynous mating is almost nonexistent in developed countries which is labelled as the mystery of monogamy (Gould *et al.*, 2008). These observations led to the following questions: why did marriage type evolve into monogamy in the course of economic development? Which factors determine the form of marriage in a given society? This paper aims to answer these questions with a simple general equilibrium model.

One of the key features of current advanced economies is that average labor income in these countries is much higher than the average in traditional societies. Moreover, both of empirical studies and growth theory show that economic development is positively associated with labor income. I base my hypothesis on this fact. I argue that the increase of labor income led to the virtual disappearance of polygyny in modern industrialized countries. Specifically, I demonstrate that above a sufficiently high level of labor income, polygynous mating disappears.

I build a framework where there are two groups of men with different income levels, while all women are identical. Each individual values consumption, spending time together (the amount of marital interaction) with the mate, number of offspring and future incomes of own children.

Men and women differ in their reproductive ability. Women are assumed to be biologically constrained to have a finite number of children and they cannot increase their offspring by increasing the number of their spouses. On the other hand, men can increase the number of their children by increasing the number of their mates. This gives men an incentive to marry polygynously and it yields competition among men for mates. All else equal, a woman's utility decreases with the number of women in the household. Since, as the number of woman increases, the marital interaction of per wife decreases. In order to marry polygynously, men have to compensate for the loss in women's utility due to lower marital interaction. The compensation takes the form of transfers to each wife and higher bequests to children more than they would get in a monogamous marriage. These economic advantages that needed to be offered in polygynous marriage also constitute the cost of polygyny for men.

Change in labor income alters the cost of polygynous mating in various ways. First, when labor income of women increases, they allocate more resources for their own consumption and leave larger bequests to their children. As a result, economic advantages provided by men in polygynous mating become relatively less important and men need to offer higher amount of resources to compensate for women's forgone utility that results from sharing their husbands with co-wives. This makes polygynous mating more costly for men. Hence, the degree of polygyny and the income of women are negatively related. Second, as labor income increases, a woman anticipates that her son will earn a higher income in the labor market. Thus, the marginal benefit that a woman derives from the bequest left to her son diminishes. Consequently, in order to convince a woman to participate in polygynous mating, men need to transfer more resources to her or increase the amount of the bequest left to her son. Hence, the incidence of polygyny declines, as labor income of children, which is equal to the return on human capital in the model, increases. Note that this change does not happen due to men's demand shift from the quantity to quality of children, known as the quantity-quality trade-off, but rather due to the increased cost of polygynous mating.

The hypothesis is consistent with existing empirical evidence. Cross-country analysis of Kanazawa *et al.* (1999) supports that increase of labor income significantly reduces polygyny. Moreover, Tertilt (2006) provide evidence on that women empowerment and the degree of polygyny are negatively correlated. Similarly, the predicted negative correlation between the socioeconomic status of women and probability of involvement in a polygynous mating is consistent with the findings of Ware (1979) and Armstrong (1993).

Surprisingly, the number of studies on the relation of monogamy and development are quite limited in economics. Becker (1991) argues that women's marginal productivity in production and care of children is higher than men's productivity. As a result, rich men have incentive to marry polygynously. However, economic development has reduced the demand of households for quantity of children and increased the demand for quality of children. Since men have greater marginal contribution to quality of children relative to quantity of them, the demand shift for quality have increased the marginal productivity of men in the production of children. This, in turn, has reduced men's incentive to marry polygynously.

Lagerlof (2005) contends that income inequality among men leads to inequality in the number of wives, as well. He argues that the decline in the incidence of polygyny in modern industrialized countries is due to the decline in income inequality among men.

Gould, Moav and Simhon (2008) explain the nonexistence of polygyny in the presence of high male inequality as a result of the trade-off between the quantity and quality of children. They argue that when the return on human capital is high, rich men may choose to marry one well-educated, high skilled woman who can provide human capital to his children, rather than mating with many women to increase the number of children. In other words, the increase in skill inequality among women led to the decline of polygyny.[1]

Previous papers do not provide a comprehensive explanation for the phenomenon. This follows from the following observations: first, the majority of primary care givers for children are still women. Second, there is a substantial income inequality in many advanced countries (Krueger *et al.*, 2008; Piketty *et al.*, 2003). Finally, there are modern societies with low level of skill inequality among women such as Nordic countries (Harkness, 2010). The distinctive mark of this study is that the hypothesis is based on a common feature of all modern industrialized countries, the increase of labor income over the course of development. The hypothesis can explain the disappearance of polygynous mating even in the absence of skill inequality among women, without changing child care roles, and even in the presence of high income inequality.

Moreover, a common feature of the existing studies in the related literature is to focus on changes in the demand for females. Lagerlof (2005) illustrates decreasing quantity of demand as a result of the decline in income inequality among men. Both Becker (1991) and Gould *et al.* (2008) explain the nonexistence of polygyny in advanced economies with men's demand shift from quantity of children to quality of children, although each of them presents a different mechanism. This paper

1. This issue is also a common research field for anthropology and sociology. In anthropology literature, Melotti (1981) explains the transition to monogamy as a result of evolution. He argues that monogamy mating is evolutionary superior to polygyny when considering altruism among children. MacDonald (1990), Betzig (1986) and Alexander (1987) argue that this phenomenon is the result of egalitarianism or the need for cohesion in democratic - industrialized countries where division of labor or 'rule of law' is prominent. In a recent paper, Lageloff (2010) extends and formalizes ideas discussed in Alexander (1987). In sociology literature, Kazanawa and Still (1999) assert that women choose to marry polygynously when wealth inequality among men is high and choose monogamy if the inequality declined sufficiently.

is the first to introduce a supply-side explanation for the phenomenon. I show that the virtual disappearance of polygyny and the presence of the quantity-quality trade-off for children arise from the increasing cost of polygyny with the increase of labor income**.** Hence, the hypothesis brings a new perspective and complements the previous studies.

The rest of the paper is organized as follows. Section 2 introduces the model. Sect. 3 examines the model and presents the results. Sect. 4 analyzes robustness of the theory. In this section, I show that the main result extends for partial female labor force participation and discuss the implications of female autonomy. Sect. 5 then provides a concluding summary.

1.2 The Model

I consider a static general equilibrium of marriage market with continuum of men and women.[2] Population sizes of both genders are equal and normalized to 1. The economy produces a single homogeneous good, using efficiency units of labor as its sole input. Output of a man and a woman is equal to, h, which is exogenously given and equivalent to human capital of a person. Human capital could be any skill which makes a person more productive in the labor market.[3] For simplicity, I normalize the cost of human capital investment to zero.[4]

Marriage occurs upon the consent of a man and a woman. Marriage in the model can be thought of as an agreement between the husband and the wife over the division of household resources among them and their children. A man can marry with a woman if he provides her with the equilibrium utility level, to be described in more detail below, determined in the competitive marriage market, u_w. Marriage is not restricted to monogamy. However, since the analysis focuses on polygyny and monogamy, I specify the utility functions so that staying single and polyandry mating are not possible in equilibrium.[5]

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2. In the Appendix C, I show that the results also carry over to a dynamic overlapping model with infinite horizon.

3. In the model economy, all women participate in the labor force. However, in Section 4, I show that the main result also extends to the partial female labor force participation.

4. Instead, one can consider that the human capital investment is costly, but the return of the human capital investment is sufficiently high that parents choose to invest in their children's human capital.

5. Polyandry marriage is the mating of a woman with plural men at the same time.

Men and women have similar preferences. Each man and woman gets utility from consumption, c_m and c_w respectively, the number and the total income of own children. Specifically, he (she) gets utility from human capital, h, of both sons and daughters. However, each parent gets utility from the total bequests left to sons only.[6] The bequest left from the father and from the mother are denoted by, b_m and b_w, respectively.

A central assumption of my model is that time spent together with the mate (emotional and sexual interaction) is a normal good for agents and the amount of marital interaction negatively depends on the number of co-wives in the household. There is a substantial empirical literature supporting this assumption. For example, estimates for joint leisure consumption by couples indicate that both men and women demand spending time together with their spouses (Hamermesh, 2002). Similarly, Sullivan (1996), Hallberg (2003), Jenkins and Osberg (2005), Connelly and Kimmel (2009) find evidence of this desire for spending time with one's spouse.[7] The literature on marital happiness and marital stability also provides evidence for the causal affect of amount of marital interaction on marital happiness (White, 1983; Hill, 1988; Zuo, 1992 and references therein). To simplify the analysis, I specify this assumption so that the difference between a woman's utility derived from time spending with her mate in monogamous mating and that of in polygynous marriage is constant, denoted by $\lambda \in \Re_+$.[8]

Men choose their quantity of children implicitly by choosing how many wives to marry, n. In order to simplify the model, I follow Becker (1991) and assume that n

6. The phylogenetic approach argues that parents transfer greater amount of wealth to their sons in order to maximize their reproductive-success (Hartung *et al.*, 1982). The specified utility functions in the model can be considered a reduced form of a more general utility function where agents care about their reproductive success. Although in the model, the gender inequality in bequests is in extreme form, relaxing this assumption does not change the results of the paper as long as male biased inequality in bequests is present.

7. Parallel to these, several empirical studies also indicate that in polygynous marriages, co-wives compete, conflict for and are jealous of sexual and emotional attention of their husbands (Meekers and Franklin, 1995; Mulder, 1990; Farrell, 1987; Solway, 1990; Aluka and Aransiola, 2003).

8. This constant utility difference can be considered as the difference between a woman's utility derived from the amount of marital interaction when she is the sole woman in the household and when she shares the amount of interaction with her mate with another woman (the lowest level of the utility difference when the number of women in the model is assumed to be discrete). Nonetheless, I show in Appendix B that the qualitative results of the model remain same when one assumes that (all else equal) a woman's utility is logarithmic function of time spent together with her mate and men divide their limited time equally among their wives.

is a continuous variable. Contrary to males, females are biologically constrained to have two children.[9] Although women cannot choose the number of their mates, they can choose whether to enter into a monogamous mating or a polygynous mating. The mating decision of a woman is denoted by $x \in \{0, 1\}$, where $x = 0$ if the mating is monogamous, and $x = 1$ if the mating is polygynous ($n > 1$).

In particular, preferences of men are represented by the following utility function

$$\ln c_m + \ln \left[n \left(2h + b_w + b_m\right)\right], \tag{1}$$

whereas a woman's utility function is given by

$$\ln c_w + \ln \left(2h + b_w + b_m\right) - \lambda x \tag{2}$$

A woman earns income in the labor market ($I_w = h$). Moreover, she receives a transfer from her husband, y. On the other hand, a man's income is the sum of bequests received from his parents and his labor income. There are two groups of men according to their income levels, *rich* with income I_r and *poor* with income I_p. Proportion of poor is given by θ and that of rich is given by $(1 - \theta)$.

A woman's and a man's budget constraints are given by

$$c_w + b_w = I_w + y \tag{3}$$

$$c_m + n \left(b_m + y\right) = I_m, \tag{4}$$

where $I_m \in \{I_r, I_p\}$

Finally, the bequest decisions of men and women are sequential. First, the husband decides the bequest level per son, b_m, and the income transfer level per wife, y. In the second stage, each wife takes the bequest and income transfer decision of the husband as given and then decides the amount of bequest, b_w, to her son. In order to simplify the analysis by avoiding corner solutions, I allow negative values of bequest left by woman, which may be interpreted as an income transfer from son to his mother after he starts to work in the labor market.[10]

9. The size of the upper bound on the women's fertility is not critical. Thus, the number of children of a woman can be assumed to be more than two. The results are valid as long as there exists a limit on the women's fertility.

10. Compared to simultaneous decision making, this bequest decision pattern is more in line with patriarchy. So, I kept intentionally the pattern in this form. However, changing the pattern does not affect the results.

1.3 Analysis

Each woman chooses her consumption, c_w, the bequest transfer to her son, b_w, and the type of mating to enter into, x, to maximize (2) subject to (3), given the amount of income transfer and the bequest left to her son by her husband:

$$\max_{\{x,\, c_w,\, b_w\}} \ln c_w + \ln(2h + b_w + b_m) - \lambda x \quad \text{s.t. } c_w + b_w = I_w + y$$

Each man chooses his consumption, c_m, the number of wives, n, the amount of income transfer to each wife, y, and the bequests for each of his sons, b_m, to maximize (1) subject to (4) and non-negativity constraints, given women's equilibrium utility, u_w:

$$\max_{\{c_m,\, n,\, y,\, b_m\}} \ln c_m + \ln[n(2h + b_w + b_m)]$$

$$\text{s.t. } c_m + n(b_m + y) = I_m, \quad b_m, y \geq 0, \quad \ln c_w + \ln(2h + b_w + b_m) - \lambda x \geq u_w$$

The last constraint can be considered as the participation constraint of a woman to enter into a polygynous mating.

Finally, market clearance implies that all women are married in equilibrium.

LEMMA 1 *In polygynous mating, the sum of the income transfer to each woman and bequest to her son is higher than the sum of those in a monogamous mating. The difference is equal to*

$$2\exp\left(\frac{u_w}{2}\right)\left[\exp\left(\frac{\lambda}{2}\right) - 1\right]$$

Proof. Substituting (3) into (2) and deriving the first-order condition with respect to b_w yield

$$b_w = \frac{I_w + y - 2h - b_m}{2} \tag{5}$$

By substituting (5) and (3) into the participation constraint, one can rewrite this constraint in the following form:

$$2\ln\left(\frac{I_w + y + 2h + b_m}{2}\right) - \lambda x \geq u_w \tag{6}$$

In the polygynous equilibrium, men's optimization requires that (6) holds with equality. Thus, (6) and $x \in \{0, 1\}$ together imply that

$$y + b_m = 2Uk - I_w - 2h \text{ if } n > 1 \tag{7}$$

$$y + b_m = 2U - I_w - 2h \text{ if } n \leq 1 \tag{8}$$

where $U \equiv \exp(\frac{u_w}{2})$ and $k \equiv \exp(\frac{\lambda}{2})$. (7) and (8) represent the sum of the income transfer to each woman and the bequest to her son in a polygynous mating and the sum of those in a monogamous mating, respectively. Subtracting (8) from (7) produces the result. ■

The intuition underlying Lemma 1 is straightforward. A man who marries polygynously provides less amount of marital interaction to each of his wives compared to a man in monogamous mating. Hence the man in polygynous mating has to compensate for each of his wive's forgone utility that results from sharing him with co-wives. There are two ways he can do this. He could offer a higher income transfer to each wife or a higher amount of bequest to her son than they would receive in a monogamous mating. The difference can be interpreted as the cost of polygynous mating for men.

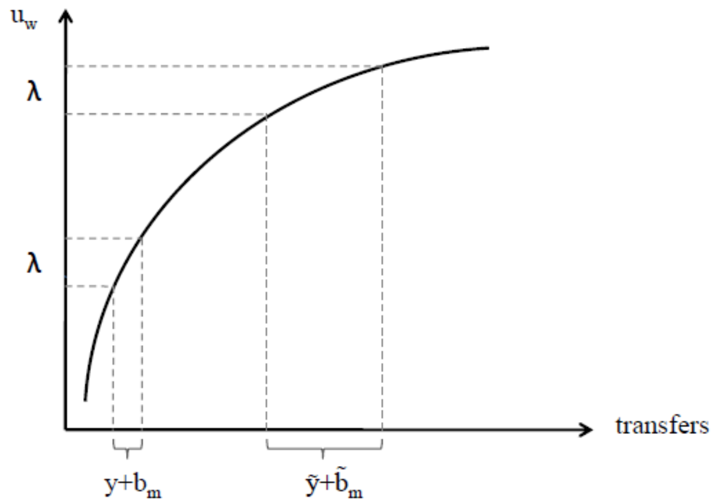

FIGURE I
Women's utility level vs. the cost of polygyny

Figure I represents the relation between the cost of polygyny and women's equilibrium utility level, u_w. It shows that as u_w increases, men need to offer higher amount of income transfer to a woman, y, and bequest, b_m, for her son in order to compensate for her forgone utility in polygyny, λ. The cost of polygynous mating increases with u_w at an increasing rate. As a result, any factor that improves women's utility also increases the cost of polygynous mating for men. Figure I shows that concavity and monotonicity properties of utility functions, which are standard assumptions, imply this result.

LEMMA 2 *Rich men have at least as many wives as poor men have.*

Proof. After substituting (4), (5) and (6) into (1), men's maximization problem boils down to

$$\max_{\{n\}} \ln\left[I_m - n\left(2Uk^x - I_w - 2h\right)\right] + \ln\left(nUk^x\right) \quad \text{s.t. } b_m, y \geq 0 \tag{9}$$

Deriving the first-order condition with respect to n produces the following conditions after rearranging:

$$n = \begin{cases} \dfrac{I_m}{2\left(2Uk - I_w - 2h\right)} & \text{if } n > 1 \\ \dfrac{I_m}{2\left(2U - I_w - 2h\right)} & \text{if } n \leq 1 \end{cases} \tag{10}$$

In the polygynous equilibrium, the characterization of n together with the assumption $I_r > I_p$ produces the result that a rich man has more wives than a poor man has. Observing that every man has one wife in the monogamous equilibrium completes the proof. ■

The cost of polygyny and the competition among males for women cause that if polygynous mating exists in equilibrium, only men with adequate resources can afford it. The assumption of balanced sex ratio in the model implies that only rich men can marry polygynously.

Lemma 2 is in line with Becker (1973), Wright (1994), and Gould *et al.* (2008) and is also consistent with existing evidence. For example, Grossbard's (1976) empirical study of polygyny at Maiduguri documents that there is a positive correlation between the degree of polygyny and male income. A similar study by Mulder (1990) in Kenya also supports this prediction.

The next proposition presents two important factors that affect the degree of polygyny.

PROPOSITION 1 *The degree of polygyny is*

i) positively associated with income inequality among males,

ii) negatively associated with the income level of women.

Proof. See the Appendix A. ■

The intuition behind the first statement of Proposition 1 is the following. Holding the income of poor men constant, an increase in the income level of rich men enlarges their choice sets. Concavity and monotonicity of the utility function imply that rich men are willing to increase the number of wives. On the other hand, holding the income of rich men constant, a decrease in poor men's income leads them to leave smaller bequests to their sons and to transfer fewer resources to their wives. This makes monogamous mating less appealing for women. As a result, more women engage in polygynous mating.

This prediction of Proposition 1 is in line with existing evidence. In their empirical study, Kazanawa *et al.* (1999) conclude that income inequality among males significantly increases the degree of polygyny. Moreover, anecdotal evidence documented by Lagerloff (2005) also supports the prediction of the first statement of Proposition 1.

The proposition also states that the income of women and the degree of polygyny are inversely related. As the income of women increases, the marginal utility of extra economic resources provided in polygynous mating diminishes. As a result, rich men have to increase the sum of income transfer and the amount of bequest, if they want to marry polygynously. The intuition for this statement follows from Lemma 1. As I show in Lemma 1, anything that increases women's equilibrium utility also increases the cost of polygyny. Thus, the increase of women's income increases the cost of polygyny through its effect on u_w.

The association between women's socioeconomic position and the degree of polygyny has been widely confirmed. The empirical studies of Grossbard (1976), Ware (1979), and Armstrong (1993) support the statement regarding the relation between the income level of women and the degree of polygyny.

Proposition 2 *The degree of polygyny declines with h and if h is sufficiently high, polygynous mating is nonexistent in equilibrium.*

Proof. See the Appendix A. ■

Proposition 2 states the main result of the paper. Above a critical level of labor income, monogamy turns out to be the unique mating type in equilibrium.[11] There are two channels in which the increase in labor income decreases the degree of polygyny, although each of these channels alone might lead to the disappearance of polygyny.

The first one is its effect through the increase of labor income of women. As I establish in the second statement of Proposition 1, women income and the degree of polygyny are inversely related. As women's income increases, so do their equilibrium utility level and the cost of polygyny (See Figure I).

Second, an increase in labor income leads women to anticipate that their sons will earn a higher income in the labor market. As a result, the benefit that women

11. The threshold of labor income is explicitly given in the Appendix A.

derive from the total bequest left to their sons diminishes. This effect coerces men to provide higher economic advantages in order to compensate for women's utility loss from polygynous mating. Hence, the cost of polygyny increases and the degree of polygyny falls.

The second channel resembles a well-known phenomenon: the quantity-quality trade-off for children. However, in contrast to the existing literature, the shift from the quantity to quality in this setting occurs due to supply-side reasons. Both Becker (1991) and Gould *et al.* (2008) argue that as the return on human capital increases, men prefer to have fewer but higher quality children. As a result, the degree of polygyny falls. On the other hand, Proposition 2 states that the decline arises from the increasing cost of polygyny rather than the demand shift of men.

To summarize, one reason that advanced countries are more monogamous than less developed ones is the differences in the level of labor income among these countries. Cross country comparisons indicate that countries with a high degree of polygyny are also the ones with the lowest GDP per capita and average labor income levels (Tertilt, 2005). The hypothesis is also is also supported by empirical evidence in the existing literature. Tertilt (2006) reports that several measures of women empowerment are negatively correlated with the degree of polygyny. Kazanawa *et al.* (1999) test the relation between the degree of polygyny and GDP per capita using cross-cultural data that includes 127 countries. Their result shows that an increase in GDP per capita significantly reduces the degree of polygyny. Since GDP per capita highly correlates with labor income, the authors conclude that their paper lends empirical support to the contention that the increase in labor income reduces the degree of polygyny.

1.4 Robustness

In the previous section, I show the transition from polygynous equilibrium to monogamous equilibrium under assumptions of full female labor force participation and ultimate female autonomy in marriage decisions. Although these assumptions are innocuous for current advanced countries, one can question their validity in the pre-industrial world. Nonetheless, I argue that the mechanism behind the main result is still effective even when these assumptions are relaxed, as I show below.

First, I investigate whether the main result hold if only a fraction of females participates in the labor force. For this purpose, I modify the model by assuming an exogenous female labor force participation rate, ε, which is less than unity. The next proposition states that the main result of the paper extends under the assumption of partial female labor force participation.[12]

PROPOSITION 3 *For all $\varepsilon \in [0,1)$, the degree of polygyny declines with h and if h is sufficiently high, polygynous mating is nonexistent in equilibrium.*

Proof. See the Appendix A. ■

The intuition behind the Proposition 3 follows from the discussion in section 2. Even if some females do not participate in the labor force, an increase in labor income still increases the equilibrium utility level of all women. Because, as labor income increases, women anticipate that labor income of their sons will increase and so the benefit of the total bequest left to sons diminishes for women. In other words, the quantity versus quality channel is effective even when some females do not work. Moreover, an increase in labor income increases the utility level of women who participate in the labor force. As argued with Lemma 1, anything that increases equilibrium utility level of women also increases the cost of polygyny. Hence, the findings are robust to the labor force participation of women.

The mechanism described in the paper is still effective in the absence of ultimate female autonomy in marital choices, as long as at least one of the following assumptions holds: (i) women have some degree of decision power over their marital choices or (ii) parents have some degree of altruism towards their daughters. The validity of the hypothesis under these assumptions is more apparent. Thus, I discuss the mechanism without presenting a formal proof. As it is in the main model, women's marginal utility derived from the economic resources provided in polygynous mating still diminishes with the increase of labor income. Since the two mechanisms in the model (the increase of labor income of women and their sons) still have the same effects on women's utility. Here, the key role of assumptions (i) and (ii) is that under either assumption, women's declining incentives to enter into a polygynous mating, accompanied with the increase of labor income, will be reflected in marital decisions. Consequently, the cost of polygynous mating for men increases with an increase in labor income and once again, the degree of polygyny being negatively correlated with labor income remains as a result.

Moreover, these assumptions are justified with evidence. There are supportive studies showing that women exert considerable influence over their marital decisions. As an instance, in Togo where more than 40% of women have been involved in polygynous union, it is documented that over 70% of women have decision power over

12. Here, I do not provide a theory of female labor force participation. Such an analysis is beyond the scope of his study.

their marital decisions (Gage, 1995). Similarly, parental altruism, that can provide alignment of interests on marital choices between daughters and their parents, is also supported by the existing studies. For example, in her analysis of 133 societies, Small (1992) concludes that the interests of females in an arranged marriage are not necessarily different from interests of their parents.

Hence, the main conclusion of the paper holds even when I relax the assumptions regarding female autonomy and labor force participation. The results crucially follow from concavity and monotonicity properties of utility functions and women's demand for marital interaction, which implies women prefer monogamy over polygyny all else equal. The first two assumptions are standard in economic theory and the last assumption is well-supported by existing empirical evidence. Consequently, the underlying mechanism works in a more general environment as long as these assumptions are preserved.

1.5 Conclusion

This paper examines why advanced countries are more monogamous than less developed countries. I build a general equilibrium model of marriage market to analyze the phenomenon and show that polygynous marriage in a society disappears, if labor income in that economy is sufficiently high.

A common feature of developed economies is that the average labor income in these countries is much higher than it is in less developed countries. I argue that this characteristic is the main reason of the variations in the degree of polygyny among advanced and less developed countries. I further assert that through the process of industrialization and economic development, the increase of labor income has led to the virtual disappearance of polygyny in advanced countries.

The theory is simple and intuitive. I assume that a woman values time spent with her spouse. If she involves in polygyny, she enjoys less utility due to less amount of marital interaction compared to she would do in monogamous mating. Thus, in order to persuade women to enter into a polygynous mating, men have to offer more economic resources than those provided in a monogamous mating. These extra payments constitute the cost of polygynous mating for men. The cost of polygynous mating for men increases with the increase of labor income through two channels: first, as labor income of women increases, the marginal benefit of the economic advantages provided in a polygynous union diminishes. As a result, women demand more to enter into a polygynous mating. Second, the increase of labor income decreases the marginal contribution of bequests to the total income. Thus, the incentives of women, who care income of their sons, to join in a polygynous mating diminish, as well. Consequently, an increase in the labor income, which is equal to the human capital return in the model, leads rich men's number of wives and children to decline. This second channel implies that the decline in quantity of children, accompanied with the increase of quality of them, arises from the supply-side changes, rather than from men's demand shift.

Moreover, the underlying mechanism yields several predictions. First, I establish that the number of wives a man has is a positive function of his income. Since polygynous mating is costly for men, only the ones with adequate resources can afford it. Moreover, income inequality among men determines the degree of competition for women. Thus, income inequality among men is positively associated with the degree of polygyny. Furthermore, the degree of polygyny is negatively related to the income level of women. This results from the increasing cost of polygynous mating with increase of women's income. All these predictions are consistent with the existing empirical findings, as is the main finding of the paper.

Finally, this paper emphasizes that women's role is as important as men's role in the determination of observed marriage types in a society. Hence, the results suggest that policies favoring women, such as encouraging their labor force participation, subsidizing female education and securing more gender equal inheritance should also be considered as alternative instruments for the prevention of polygyny.

1.6 Appendix A: Proofs

NOTATION 1 *Let n be an element of the set $\{n_r, n_p\}$ where n_r and n_p are the numbers of wives of a rich man and a poor man, respectively. Let L and M denote the exogenous bequests received by a rich and a poor man, respectively.*

Proof of Proposition 1. Substituting (10) into the market clearing condition ($\theta n_p + (1-\theta) n_r = 1$) produces the following equation.

$$U = \frac{(k+1)(4h+2I_w) + k\theta I_p + (1-\theta) I_r \pm \sqrt{A}}{8k} \tag{A-1}$$

where $A \equiv [(1-\theta)I_r - k\theta I_p - (k-1)(4h+2I_w)]^2 + 4I_r k\theta I_p(1-\theta)$. It gives an expression of U in terms of the exogenous variables for the polygynous equilibrium. Notice that although U has two roots, the root with negative $\sqrt{A}$ violates (10). Therefore, the positive root represents U.

Substituting (A1) into (10) yields

$$n = \frac{I_m}{\frac{(k+1)(4h+2I_w)+k\theta I_p+(1-\theta)I_r+\sqrt{A}}{2} - 2I_w - 4h} \text{ if } n > 1$$

In Lemma 2, I establish that if the equilibrium is polygynous, only rich men marry polygynously. Thus, the number of a rich man's wives is equal to the following:

$$n_r = \frac{I_r}{\frac{(k+1)(4h+2I_w)+k\theta I_p+(1-\theta)I_r+\sqrt{A}}{2} - 2I_w - 4h} \tag{A-2}$$

Taking the derivative of n_r with respect to I_r and I_p shows that $\partial n_r/\partial I_r > 0$ and $\partial n_r/\partial I_p < 0$. Therefore, n_r is negatively related to income inequality.

Taking the derivative of n_r with respect to I_w yields $\partial n_r/\partial I_w < 0$ which proves the second statement of Proposition 1.[13] ■

Proof of Proposition 2. First, I need to show that $\partial n_r/\partial h < 0$. After replacing I_w with its equivalent h, I_r with $L + h$ and I_p with $M + h$, n_r can be written as the following:

$$n_r = \frac{L + h}{4Uk - 6h} \tag{A-3}$$

Similarly, the number of wives of a poor man in the polygynous equilibrium is equal to

$$n_p = \frac{M + h}{4U - 6h} \tag{A-4}$$

The exact expression of the derivative, $\partial n_r/\partial h$, is quite complex and it is hard to determine the sign of it. Thus, I prove that $\partial n_r/\partial h < 0$ with a proof by contradiction.

First notice that $\partial n_r/\partial h$ and $\partial n_p/\partial h$ have opposite signs. Because the proportions of rich and poor men and the sum of n_r and n_p is constant. Now, for a contradiction, assume that $\partial n_r/\partial h > 0$. This implies

$$\frac{\partial n_p}{\partial h} = \frac{2U + 3M - 2(M + h)(\frac{\partial U}{\partial h})}{2(3h - 2U)^2} < 0 \tag{A-5}$$

(A5) implies

$$\frac{\partial U}{\partial h} > \frac{2U + 3M}{2(M + h)} \tag{A-6}$$

13. The derivates are calculated with Maple and the program codes are available.

Taking the derivative of n_r with respect to h yields

$$\frac{\partial n_r}{\partial h} = \frac{-2(L+h)(\frac{\partial U}{\partial h}) + 2kU + 3L}{2(2Uk-3h)^2} > 0 \tag{A-7}$$

(A7) implies

$$\frac{\partial U}{\partial h} < \frac{2Uk+3L}{2k(L+h)} \tag{A-8}$$

(A6) and (A8) together yield

$$\frac{2U+3M}{2(M+h)} < \frac{2Uk+3L}{2k(L+h)} \tag{A-9}$$

However, (A1) implies that $U > 6(k+1)h/8k$. Also, $k > 1$ implies $(L-M) > (L-kM)$. These two properties together result in

$$\frac{2U+3M}{2(M+h)} \nless \frac{2Uk+3L}{2k(L+h)} \tag{A-10}$$

which is a contradiction. Equating $\partial n_r/\partial h$ to zero yields a similar contradiction. Hence, the sign of the derivative, $\partial n_r/\partial h$, is negative.

In the second part of the proof, I show that if h is higher than a critical level, the marriage market equilibrium is monogamous. (10) together with Lemma 2 imply the following two conditions.

$$\frac{I_r}{2} > 2Uk - I_w - 2h \tag{A-11}$$

$$\frac{I_p}{2} \leq 2U - I_w - 2h \tag{A-12}$$

Multiplying each side of (A12) with k and combining it with (A11) yield

$$\frac{L+h}{2} + h + 2h > 2Uk \geq \left(\frac{M+h}{2} + h + 2h\right) k \tag{A-13}$$

Hence, in the polygynous equilibrium, in addition to (10), (A13) should hold. Otherwise, n_r cannot be larger than 1. Now, rearranging (A13) yields

$$\frac{L-kM}{7\,(k-1)} > h \tag{A-14}$$

Consequently, if $h \geq (L-kM)/7(k-1)$, the marriage market equilibrium cannot be polygynous. This proves the proposition. ■

Proof of Proposition 3. In the previous proposition, I establish that in the case with full female labor force participation ($\varepsilon = 1$), if h is sufficiently high, polygynous mating is nonexistent in equilibrium. Now, let female labor force participation rate to be zero. This corresponds to equating I_w to zero in (A3) and yields

$$n_r = \frac{I_r}{\frac{(k+1)4h+k\theta(M+h)+(1-\theta)(L+h)+\sqrt{D}}{2} - 4h} \tag{A-15}$$

where $D \equiv [(1-\theta)I_r - k\theta I_p - (k-1)(4h)]^2 + 4I_r k\theta I_p(1-\theta)$.

Taking the derivative of n_r with respect to h yields $\partial n_r/\partial h < 0$. This shows that the degree of polygyny falls with the increase of h even if female labor force participation is assumed to be zero. Similarly, equating I_w to zero in (A11) and (A12) produces a necessary condition for the existence of the polygynous equilibrium when none of the females participates in the labor force.

$$\frac{L+h}{2} + 2h > 2Uk \geq \left(\frac{M+h}{2} + 2h\right) k \tag{A-16}$$

Rearranging (A16) yields

$$\frac{L-kM}{5\,(k-1)} > h \tag{A-17}$$

(A17) shows that in the case of zero female labor force participation, if $h \geq (L - kM)/5(k-1)$, the marriage market equilibrium is monogamous. Hence, for all $\varepsilon \in [0,1]$, there exists $h^* \in \Re_+$ such that if $h \geq h^*$, polygynous mating is nonexistent in equilibrium. This completes the proof. ■

1.7 Appendix B: Spouses' Shared Time

In this section, I argue that keeping the difference between utility derived from the amount of marital interaction in monogamous mating and that of in polygynous mating constant is harmless. Specifically, I show that the qualitative results of the paper remain same in a model where a woman's utility is logarithmic function of time spent together with her mate and men divide their limited time equally among their wives.[14]

14. Since polyandry marriage is ruled out in the model, men's valuation of their time spent with their wives is normalized to zero. One can consider that a man's total amount of time spending together with his mates does not change with the increase of the number of his mates since he devotes his limited time among them. Nonetheless, relaxing this assumption does not change qualitative results of the paper, because the channel of increase of the cost of polygyny, accompanied with the increase of labor income, will still be effective.

Now, the new utility function of a woman takes the following form:

$$\ln c_w + \ln(2h + b_w + b_m) + \ln(\frac{T}{n}) \tag{A-18}$$

where $T \in \Re_+$ denotes the amount of a man's time endowment and n denotes the number of women in the household. Other specifications of the main model remain same. A man can marry with a woman if he provides her with the equilibrium utility level determined in the competitive marriage market. This implies the following constraint:

$$\ln c_w + \ln(2h + b_w + b_m) + \ln(\frac{T}{n}) \geq u_w \tag{A-19}$$

Substituting (3) and (5) into (A19) yields

$$\ln\left(\frac{I_w + y + 2h + b_m}{2n}\right) \geq \frac{u_w - \ln(T)}{2} \tag{A-20}$$

men's optimization requires that (A20) holds with equality. After arranging, this implies:

$$y + b_m = 2nVs - I_w - 2h \tag{A-21}$$

where $V \equiv \exp(\frac{u_w}{2})$ and $s \equiv \exp(\frac{\ln(T)}{2})$. (A21) indicates that the sum of the income transfer to each woman and bequest to her son increases with the number of women in the household. Hence, in polygynous mating, the sum of the income transfer to each woman and the bequest to her son is higher than the sum of those in a monogamous mating. This shows the result stated in Lemma 1 also holds in this framework.

After substituting (4), (5) and (A21) into (1), men's maximization problem boils down to

$$\max_n\{\ln[I_m - n(2nVs - I_w - 2h)] + \ln\left(Vsn^2\right)\} \quad \text{s.t. } b_m, y \geq 0 \tag{A-22}$$

Deriving the first-order condition with respect to n produces the following conditions after rearranging:

$$n = \frac{\sqrt{64I_mVs + 9(I_w + 2h)^2} + 3(I_w + 2h)}{16Vs}$$

This yields the following equations:

$$n_r = \frac{\sqrt{64I_rVs + 9(I_w + 2h)^2} + 3(I_w + 2h)}{16Vs} \tag{A-23}$$

$$n_p = \frac{\sqrt{64I_pVs + 9(I_w + 2h)^2} + 3(I_w + 2h)}{16Vs} \tag{A-24}$$

The characterization of n together with the assumption $I_r > I_p$ produces the result stated in Lemma 2 that in the polygynous equilibrium, a rich man has more wives than a poor man has.

Substituting (A23) and (A24) into the market clearing condition yields:

$$\frac{\sqrt{64I_pVs + 9(I_w + 2h)^2} + 3(I_w + 2h)}{16Vs/\theta} + \frac{\sqrt{64I_rVs + 9(I_w + 2h)^2} + 3(I_w + 2h)}{16Vs/(1-\theta)} = 1$$

We can determine the derivative of V with respect to I_p, I_r, I_w by applying implicit differentiation to the market clearing condition. After that, taking the derivative of n_r with respect to I_p, I_r yields $\partial n_r/\partial I_p < 0$ and $\partial n_r/\partial I_r > 0$ that shows the degree of polygyny is positively associated with income inequality among males. Similarly, taking the derivative of n_r with respect to I_w yields $\partial n_r/\partial I_w < 0$ that shows the degree of polygyny is negatively associated with the income level of women. Hence, the results stated in Proposition 1 are still valid.

After replacing I_w with its equivalent h, I_r with $L + h$ and I_p with $M + h$, the equation that characterizes n_r can be written as the following:

$$n_r = \frac{\sqrt{64(L + h)Vs + 81h^2} + 9h}{16Vs}$$

After making the same replacements in the market clearing condition and determining the derivative of V with respect to h by applying implicit differentiation, the derivative of n_r with respect to h results $\partial n_r/\partial h < 0$.[15] This indicates that the degree of polygyny declines with the increase in labor income, h. Equating I_w to zero in (A23) and applying the same technique results that the degree of polygyny declines with the increase in labor income, even none of women participates to the labor force. Hence, the qualitative results of the paper extends under the new assumptions.

1.8 Appendix C: Dynamic Extension

In this section, I present a dynamic extension for the model. I show that my results carry through to a dynamic overlapping generations model with infinite horizon. Let superscript t denotes period t and L^0 and M^0, where $L^0 > M^0$, denote the assets of initial rich and poor, respectively. I assume that h increases with time, i.e. $h^{t+1} > h^t$. At time t, a woman's income is equal to h^t and a man's income is equal

15. The derivates are calculated with Maple and the program codes are available.

to the sum of the human capital return in that period, h^t and the bequests that he receives from his parents, b_w^{t-1} and b_m^{t-1}, where $b_m^{t-1} \in \{b_r^{t-1}, b_p^{t-1}\}$.

First, notice that the results stated in Lemma 1 and 2 and Proposition 1 are time invariant. Thus, the results are still valid. Moreover, the following equation, which is counterpart of (A14), shows the necessary condition for the existence of the polygynous equilibrium in the dynamic model.

$$\frac{L^{t-1} - kM^{t-1}}{7\,(k-1)} > h^t \tag{A-25}$$

Substituting (5) into (7) and (8) imply that in the polygynous equilibrium, total bequests received by rich and poor men at time t are equal to

$$b_w^{t-1} + b_m^{t-1} = U^{t-1}k - 2h^{t-1} \text{ if } n^{t-1} > 1 \tag{A-26}$$

$$b_w^{t-1} + b_m^{t-1} = U^{t-1} - 2h^{t-1} \text{ if } n^{t-1} \leq 1 \tag{A-27}$$

Multiplying (A27) with k and subtracting the outcome from (A26) yield

$$L^{t-1} - kM^{t-1} = 2(k-1)h^{t-1} \tag{A-28}$$

(A28) implies that at time t, the necessary condition for the polygynous equilibrium, (A25), is not satisfied and as a result, polygynous mating disappears. I should note that the pass to the monogamous equilibrium is rapid. After initial period, polygynous mating disappears. However, the pace of the transition depends on the structure of wealth transmission and specification of the utility functions.

Next, I show that the endogenous income inequality preserves in both polygynous and monogamous equilibrium. First, in the polygynous equilibrium, (A26) and (A27) imply that income inequality among males at time t is equal to $U^{t-1}(k-1)/(U^{t-1} - 2h^{t-1} + h^t)$ and it is greater than zero. In the monogamous equilibrium, solution of women's problem results

$$b_w^{t-1} = \frac{h^{t-1} + y^{t-1} - 2h^t - b_m^{t-1}}{2} \tag{A-29}$$

and given $n = 1$, the solution of men's problem implies

$$y^{t-1} + b_m^{t-1} = \frac{I_m^{t-1} - h^{t-1} - 2h^t}{2} \tag{A-30}$$

Substituting (A29) into (A30) yields

$$b_w^{t-1} + b_m^{t-1} = \frac{h^{t-1} - 6h^t + I_m^{t-1}}{4} \tag{A-31}$$

This shows that if the equilibrium is monogamous, the inequality in period t is equal to $\left(I_r^{t-1} - I_p^{t-1}\right) / \left(4I_p^t\right)$ and once again it is greater than zero. Hence, I establish that the endogenously determined income inequality preserves both in polygynous and monogamous equilibrium.

The simple model that I present above does not provide a good representation of the distribution and intergenerational transmission of wealth. One need a more sophisticated model to do this. One possibility is to allow for bequest inequalities among sons, i.e., modelling primogeniture.[16] However, my analysis is on marriage types and not on the transmission of wealth. Also, this simple model still shows that inferences of the static model hold in the dynamic extension. Hence, in order to preserve simplicity, I kept the model intentionally in this simple form.

16. Primogeniture is the custom that the eldest son receives nearly all of total bequest left. See DeLong (2003), Bertocchi (2006) for an extensive discussion of the issue.

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CHAPTER 2

THE MASQUERADE BALL OF THE CEOs AND THE MASK OF EXCESSIVE RISK[17]

2.1 Introduction

Excessive risk taking by the CEOs of large financial cooperations is widely believed to have played a great role in the economic and financial crisis of 2008-2009 (Blinder, 2009). Of the executives and commentators surveyed in the financial services sector, 73% consider excessive risk taking to be one of the crucial factors that triggered the crisis (PricewaterhouseCoopers, 2008). G-20 leaders announced their commitment in legislating the necessary changes to minimize excessive risk taking. The Basel II framework has been amended to account for motives to take excessive risk. The Dodd-Frank Act prohibited certain compensation arrangements in order to discourage inappropriate risk taking by financial institutions in the US. What motivates CEOs to employ excessively risky projects? Two well-known explanations are limited liability, which provides insurance to CEOs against the downward risks of their project choice, and compensation schemes that encourage risk taking (*e.g.,* convex compensation schemes). In this paper, we provide an additional reason for why there might be excessive risk taking in the market even in the absence of limited liability and compensation schemes that encourage risk taking. We argue that a CEO's career concerns regarding potential termination give her incentive to try to improve the market's expectation about her managerial ability. We show that a CEO can achieve this goal by choosing excessively risky projects and that, under certain conditions, explicit incentives provided by optimal linear compensation contracts cannot prevent CEOs from choosing such projects.

We build a principal-agent framework in which a (risk-neutral) firm operates for two periods. We initially assume that there are two types of (risk-neutral) CEOs, high- and low-ability, who are equally likely in the population. Neither the firm nor the CEO knows the ability of the CEO in the beginning (in the asymmetric information section, the CEO knows her ability). The CEO chooses the project to be undertaken by the firm from a pool of investment projects. Projects differ in their probabilities of failure and potential returns, and there is a high risk-high return / low risk-low return technology in the sense that a project with a higher

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probability of failure has a higher return in the good state and higher loss in the bad state (as in bank loans or CDOs which are split into different tranches according to their default risk and returns). Among the potential projects, there are excessively risky ones with lower expected returns and higher probabilities of failure, some even with negative NPVs which are in fact chosen in equilibrium. In the end, the firm may land in one of the two possible states (good or bad) and pays the optimal linear compensation contract that allows for any combination of fixed wages and stocks, so there is no compensation arrangement that increase risk appetite, such as convex compensation schemes. A loss is incurred by the CEO if the output realization is negative, so there is no limited liability.

If the firm believes that the ability of the CEO is below average at the end of the first period, it fires her and hires a new CEO, whose ability is expected to be average in the population. This layoff risk is the source of the CEO's career concerns and it gives her incentive to improve the market's expectation about her ability.[18] Suppose, for the moment, that the CEO knows her ability (as we do in the asymmetric information section) and it is low. In such as case, she can simply "gamble" by choosing an excessively risky project. When the good state realizes, the firm cannot be sure if the observed output is produced by a low- or high-ability CEO. However, it has to statistically conclude that the CEO is more likely to be a high-ability one in the bad state as the probability of success is lower with excessively risky projects. When the bad state realizes, the firm infers the type of the CEO and fires her. But, if she did not choose an excessively risky project, she would be fired in any output realization. This means that she can lower her probability of being fired by choosing an excessively risky project.

More importantly, a CEO who does not know her ability also has the same motivation. Because she takes into account the possibility that her type might be low, she tries to prevent the firm from perfectly inferring her type. In our model, she can do so by choosing the excessively risky project with which the good-state

18. It is noteworthy that risk-taking decisions interact with layoff risk and compensation incentives in practice. Kempf, Ruenzi, and Thiele (2009) empirically show that layoff risk and compensation effects matter in managers' risk-taking decisions. Chevalier and Ellison (1999) mention that avoiding a possible layoff is the most important career concern. Other papers supporting this hypothesis include Fama (1980), Jensen and Murphy (1990), Berger, Ofek, and Yermack (1997), Bloom and Milkovich (1998), Mehran, Nogler, and Schwartz (1998), Wiseman and Gomez-Mejia (1998), Eckbo and Thorburn (2003), Hong and Kubik (2003), Clarke and Subramanian (2006), Chakraborty, Sheikh, and Subramanian (2007), and Larraza-Kintana *et al.* (2007). The literature also shows that CEO turnover is closely related to the peer performance (Gibbons and Murphy, 1990; DeFond and Park, 1999; Kaplan and Minton, 2012).

output of a low-ability CEO coincides with the bad-state output of a high-ability one. When the firm observes this "overlapped" output, it cannot know exactly which ability type in fact produced this output. However, because the probability of failure is higher with an excessively risky project, the firm believes that the observed output is more likely to be the bad-state realization of a high-ability CEO than the good-state realization of a low-ability one. Consequently, the firm's expectation about the CEO's ability will be higher than average even though each type is *ex ante* equally likely, which means that the CEO is not fired in such an output realization. In fact, by following this strategy, she is fired only if she turns out to be a low-ability CEO in the bad state.

We show that the strategy of overlapping the outputs by choosing an excessively risky project minimizes the probability of being fired when the difference between the two possible abilities is neither too high nor too low. Yet, minimizing the probability of being fired is not automatically an equilibrium. It is so when the CEO's compensation benefit she derives by choosing the optimally risky project in the first period is dominated in expected payoff by the career benefit she derives by choosing an excessively risky project to minimize her probability of being fired. In such a case, excessively risky projects are undertaken in equilibrium under the optimal linear compensation contract. This sheds light on the ongoing debate about the (desperate) role of regulation of compensation structures to prevent excessive risk taking.

Policy debates emphasize the CEOs' *responsibility* in the inefficiently high levels of risk taken by large financial corporations. Yet, we show that, in addition to cases in which the firm *involuntarily* allows the CEO to choose excessively risky projects, there are also cases in which it *voluntarily* allows her to do so. In the former case, the firm allows the CEO to choose an excessively risky project because no compensation contract, not even providing the whole return of the project to the CEO, can have her choose the optimally risky project. However, in the latter case, although having the CEO choose the optimally risky project could be profitable for the firm, letting her choose an excessively risky project is even more profitable. This is inefficient from the point of view of society, as the return from an excessively risky project has negative net present value. Thus, shareholders sometimes share the responsibility of inefficient levels of risk in the firm.

Our results hold even when CEOs are risk averse. We further show that excessively risky projects are undertaken even when there is a continuum of ability types. This case also illustrates an inverse U-shaped relationship between the unobserved ability of the CEO and her layoff risk. Among the below-average CEOs, a higher-ability one is more likely to be fired than a lower-ability one, while above-average

CEOs face no layoff risk. Finally, we show that our results are robust to changes in informational assumptions by illustrating that excessively risky projects are undertaken in equilibrium when CEOs privately know their types. Our explanation for excessive risk taking is not limited-liability based, as there is no limited liability for the CEO in the model. That is, in our setting, a CEO does not take higher risks simply because limited liability protects her from downward risks, which is already a well-known explanation. As a matter of fact, incorporating limited liability to our setting would increase CEOs' risk appetite. Our explanation is not based on convex compensation schemes, the other popular explanation for excessive risk taking, either, as we do not allow for them in the optimal contract.

We now explain how our paper relates to prior work. A large body of literature, pioneered by Fama (1980) and Holmstrom (1982/1999), analyzes how career concerns affect the behavior of agents. Holmstrom (1982/1999) finds that, since investing in a project carries the risk of one's type being discovered, a risk-averse manager behaves overly conservatively by not investing in risky projects at all. Holmstrom and Ricart i Costa (1986) elaborate on this idea further and show that conservatism can be fixed if the shareholders can offer a downward rigid wage. Building on Holmstrom's findings, the literature that followed has focused on *managerial conservatism* in a broad sense (see, *e.g.*, Narayanan, 1985; Stei,n 1988; Shleifer and Vishny, 1989; Hirshleifer and Thakor, 1992; Milgrom and Roberts, 1992; Zwiebel, 1995; Nohel and Todd, 2005; and Malcomson, 2011). Contrary to this literature, we show that managers with career concerns (even risk-averse ones) have an incentive to choose excessively risky projects.

Some papers focus on the possibility of signaling of managerial ability. Huberman and Kandel (1993) analyze the reputation concerns of money managers who might possibly overinvest in a risky asset to signal their ability. Huddart (1999) shows that an explicit performance fee may mitigate excessive risk taking of investment advisors who have reputational concerns. Unlike the signaling literature, in our setting the CEO is trying not to flaunt her type but to rather add bias to the market's inferences about it. In that sense, our mechanism is closer to the signal-jamming literature, in which the agent tries to "jam the signal" about her type (Fudenberg and Tirole 1986).

The recent literature on CEO turnover analyzes the impact of performance risk on the firm's ability to infer the unknown ability of its CEO. For example, Bushman, Dai, and Wang (2010) analyze whether firm-specific or systematic risk increases turnover in a setting where risk is exogenous. Instead, we look at the implications of CEO turnover for risk taking when both the risk choice of the CEO and the turnover decision of the firm are endogenous. Hu *et al.* (2011) find a U-shaped relationship between the manager's risk choice and her *prior* relative performance among her peers. We find a similar inverse U-shaped relationship between the CEO's ability and her layoff risk. In our setting, while above-average CEOs face no layoff risk, among below-average ones, lower-ability CEOs have lower layoff risk than do higher-ability ones.

The type of statistical bias that managers try to add into the market's inference about their unknown abilities appears in various ways in the literature. In Milbourn, Shockley, and Thakor (2001), in order to alter the market's assessment about her ability, the manager distorts the probabilities of reputational states that are observed and not observed by overly investigating potential projects. In Scharfstein and Stein (1990), the motivation of the manager is to minimize reputational risk by following the crowd. The closest in spirit to our paper is Hermalin (1993). Because the project choice is observable in Hermalin (1993), a manager can decrease the variance of the posterior estimate of her ability by choosing the riskiest project in terms of variance, as a result of which the principal puts more weight on his prior assessment of the CEO's ability. The intuition for this result can be easily seen with an extreme example. A manager can minimize reputational risk by investing in the projects with infinite risk, as this would be no more informative than not investing at all. In our setting, rather than affecting the weights on assessments, the CEO is able to influence the posterior assessment itself.

The paper is organized as follows. Section outlines the model. Section analyzes the case in which the CEOs managerial ability is unknown but the project chosen by them is privately known. Section extends the two-type analysis of the previous sections to a continuum of types. Section goes back to the two-type world but extends the model in another dimension by assuming that CEOs privately know their managerial abilities. Section concludes. An appendix contains further details and proofs.

2.2 The Model

We consider a unit mass of risk-neutral CEOs, each of whom may potentially be employed by a risk-neutral firm. CEOs differ in their innate *managerial ability*, which is represented by θ_i, where $i = \{H, L\}$ and $\theta_L < \theta_H$. A CEO with a managerial ability of θ_L (θ_H) is called a *low-ability (high-ability) CEO*. Each type is equally likely in the population, and thus the average ability of a CEO is $\bar{\theta} := (\theta_H + \theta_L)/2$. No one, including the CEO herself, knows the type of a CEO, but the distribution of types in the population is common knowledge. Thus, all parties, including the CEO herself, hold identical prior beliefs over managerial ability. Given her managerial ability, she chooses her "managerial action", or the project to be undertaken by the firm. Projects differ in their probability of failure, $r \in [0,1]$, which is privately known by the CEO.[19] There is no borrowing and lending, and neither the firm nor the CEOs discount future payoffs.

The firm operates for two periods, $t = \{1, 2\}$. The output of the firm in any period is determined by both the managerial ability of and the project choice by its current CEO.[20] If a CEO of managerial ability θ_i chooses a project with probability of failure r_t in period t, then the *realized* output of the firm, $y_t(\theta_i, r_t)$, is

$$y_t(\theta_i, r_t) = \begin{cases} \theta_i - f(r_t) & \text{with probability } r_t \\ \theta_i + f(r_t) & \text{with probability } 1 - r_t, \end{cases} \quad (1)$$

where $f(r_t)$ is an increasing, concave, and twice-continuously differentiable *managerial action-return function* with $f(0) \geq 0$. We keep this technological specification fixed throughout the paper. The reservation payoff of a CEO per period is $\underline{u}$, which satisfies $0 < \underline{u} \leq \theta_L$. Thus, the firm may find it profitable to hire a CEO by paying at least her reservation payoff.

The *expected* output of the firm in period t, $E[y_t]$, is[21]

$$E[y_t(\theta_i, r_t)] = \theta_i + (1 - 2r_t) f(r_t) \quad \forall t = \{1, 2\}, \quad \forall i = \{H, L\}. \quad (2)$$

Given the managerial ability, we interpret this technology as a collection of investment projects with different realized returns and probabilities of failure pairs resulting in different expected values for each project. In a large number of papers, the choice is between a risky and a riskless project. Our technological specification

19. In Holmstrom (1982/1999), Holmstrom and Ricart i Costa (1986), and Hermalin (1993), observability of project choice and risk aversion are crucial to the obtained results. In our setting, we do not need to assume that the project choice is unobservable as long as CEOs do not know their abilities because the market correctly predicts this anyway. However, this assumption will be crucial in the asymmetric information case in which CEOs privately know their abilities and each type chooses projects with different probabilities of failure in equilibrium.

20. This specification is consistent with the evidence showing that not only the managerial ability (Chevalier and Ellison, 1997; Sirri and Tufano, 1998; Del Guercio and Tkac, 2002; Falato, Li, Milbourn, 2010) but also the managerial style (in our case the project choice) (Bertrand and Schoar, 2003) matter in the firm.

21. The assumption that θ_i enters the production technology linearly is quite common in the literature and it is assumed only for simplicity. One can generalize the analysis by having $E[y_t(\theta_i, r_t)] = g(\theta_i) + (1 - 2r_t) f(r_t)$, and this does not change the qualitative results as long as $g(\theta_i)$ is an increasing function.

is a generalization of this assumption to many projects. With this specification, an increase in the probability of failure increases the output in the good state and the loss in the bad state. Hence, there is an *optimally risky project* with $r_t^* < 1$ that maximizes the expected output of the firm. Our technological specification makes good sense in many real-life situations, especially in those involving risky financial investments. We now define what we mean by an *excessively risky project.*

DEFINITION 1 (EXCESSIVELY RISKY PROJECT) *An excessively risky project has a lower expected return but higher probability of failure than the optimally risky project.*

An excessively risky project is second-order stochastically dominated. However, what we find will be even stronger than this. We show that the expected return from managerial action, $(1 - 2r_t)f(r_t)$, is negative valued for the excessively risky project chosen in the equilibrium. That is, the CEO chooses a project with so high probability of failure that it results in negative expected return from the contribution of managerial action to the output. Thus, she chooses a negative NPV project in equilibrium in terms of the return from managerial action.

Contracting between the firm and the CEO is fairly simple. We assume that the firm is not able to offer two-period contracts.[22] Thus, in each period, the firm offers the CEO an individually rational and incentive-compatible compensation contract. We restrict our attention to linear contracts, as our goal is to show that excessively risky projects are undertaken even in the absence of compensation contracts that increase risk appetite such as convex compensation schemes.[23] The realized compensation of the CEO in period t, w_t, is given by

$$w_t\left(a_t, b_t, y_t\left(\theta_i, r_t\right)\right) = a_t + b_t y_t\left(\theta_i, r_t\right) \quad \forall t = \{1, 2\}, \quad \forall i = \{H, L\}, \tag{3}$$

where $a_t \geq 0$ and $b_t \in [0, 1]$ are compensation parameters. If $b_t = 0$ and $a_t > 0$ in equilibrium, then the contract is a fixed-wage contract, and if $b_t > 0$ and $a_t = 0$,

22. We make this assumption to be able to analyze the relationship between layoff risk and managerial risk taking, which requires focusing on a contract renewal period. This is also a standard assumption in career concern models (Gibbons and Murphy, 1992; Hermalin, 1993; Dasgupta and Prat, 2006; Bushman, Dai, and Wang, 2010). Hermalin (1993) argues that it is usually infeasible to commit fully to employ the manager at a prespecified compensation in the future.

23. If we allow for stock options in addition to stocks, the incentives will be even more skewed toward choosing excessively risky projects (see, *e.g.*, Lambert, 1986; Ju, Leland, and Senbet, 2003; Mehran and Rosenberg, 2007; Raviv and Landskroner, 2009; Dong, Wang, and Xie, 2010). Moreover, as Murphy (1999) mentions in his well-known review of executive compensation, stock ownership is the most direct way of aligning the preferences of CEOs and shareholders.

then it provides stock ownership only. All other combinations involve both a fixed wage and stock ownership simultaneously.

Because the CEO's managerial ability is unobserved, the first-period output of the firm is a predictor of her future productivity. Hence, her layoff risk in the second period is influenced by the realized output in the first period, which is influenced by her project choice. This creates the CEO's career concern in our setting and results in a misalignment between her and the firm's preferences. The CEO maximizes her two-period expected compensation by choosing a project in each period, while the firm engages in period-by-period maximization and makes a firing decision in between the two periods, if necessary, upon updating its beliefs based on the first-period output realization.

The sequence of events is as follows. At the beginning of the first period, the firm signs a contract with a CEO that specifies her compensation in this period. Upon employment, the CEO chooses a project, whose probability of failure is represented by r_1. Then, the first-period output y_1 is realized. The firm pays w_1 to the CEO, updates its beliefs about her managerial ability based on the realized output, and decides whether to fire her. We call a CEO who is hired again in the second period an *old CEO*; and if the firm hires a new CEO in the second period, we call her a *new CEO*. Depending on its firing decision, at the beginning of the second period, the firm signs a new compensation contract with either the old or a new CEO. The CEO chooses a project, whose probability of failure is represented r_2, for the second period. Finally, the second-period output y_2 is realized, the CEO is paid w_2, and the firm is dissolved.

As a benchmark, we first characterize the complete information setting in which both the managerial ability and the project choice of the CEOs are observable. Obviously, the firm wants to employ a high-ability CEO, and this CEO has no career concern as there is no risk of being fired. As a result, we can obtain the optimally risky project with probability of failure r_t^* from the joint surplus maximization, $\max_{r_t}\{E[y_t(\theta_H, r_t)]\}$, whose first-order condition yields $2f(r_t) = (1-2r_t)f'(r_t)$, from which we can easily see that the optimally risky project's probability of failure level satisfies $r_t^* < 1/2$ in any interior solution.[24] The CEO earns just her reservation payoff in expected terms in the optimal compensation contact, which may involve fixed wage and stock ownership in various combinations.

24. The second-order condition, $-4f'(r_t) + f''(r_t)(1 - 2r_t) \leq 0$, holds for all $r_t < 1/2$.

2.3 Symmetric-Incomplete Information Case

In the symmetric-incomplete information setting, neither the CEO nor the firm knows the type of the CEO, and only the CEO knows her project's probability of failure. We proceed backwards to solve the model. The next subsection analyzes the second period and shows that the CEO, whether new or old, chooses the optimally risky project in the second period because she no longer has any career concern in this period as the firm will be dissolved after that. It also shows that the firm fires a CEO at the end of the first period if and only if, upon observing the first-period output, it believes that the CEO's ability is less than the average ability in the population. The subsection following the next analyzes the first period and shows that choosing an excessively risky project can be an equilibrium when the difference between the abilities is neither too high nor too low.

The Second Period

This subsection derives the firm's optimal firing rule and obtains the project that a CEO chooses in the second period. Because the CEO has no career concern in the second period, the problem that the firm faces is a standard moral hazard problem whose solution leaves no surplus to the CEO, who eventually chooses the optimally risky project.

The firm maximizes expected output net of expected CEO compensation subject to the individual rationality constraint, which guarantees that the CEO finds it better to sign the compensation contract than to pursue her outside option, and the incentive compatibility constraint, which guarantees that the firm's maximization problem is consistent with the project choice that results from the CEO maximization problem. The incentive compatibility constraint is given by

$$r_2 \in \arg\max_{\hat{r}_2} E\left[a_2 + b_2\left(\theta + (1 - 2\hat{r}_2)\, f\left(\hat{r}_2\right)\right)\right]. \tag{4}$$

The CEO does not know her ability but rationally expects it to be $\bar{\theta}$ if she is a new CEO. If she is an old CEO, then all terms are conditional on the first-period output realization. Thus, her type is expected to be $\tilde{\theta} := E[\theta_i \mid y_1(\theta, r_1)]$, which is her expected ability given the first-period output $y_1(\theta, r_1)$.

Because the expected compensation is a concave function of r_2 for its positive range, we can comfortably replace the incentive compatibility constraint with its first-order condition. Yet, this first-order condition is exactly the same as the first-order condition of the complete information setting as long as the compensation contract includes some stock ownership (*i.e.*, $b_2 > 0$). Hence, the CEO, whether new or old, chooses the optimally risky project with r_2^* in equilibrium.[25] The firm adjusts the compensation parameters such that the individual rationality constraint binds in equilibrium and the CEO gets exactly her reservation payoff, $\underline{u}$, in expected terms. This analysis leads to the following proposition.

Proposition 4 (Project choice in the second period) *The CEO, whether old or new, chooses the optimally risky project with r_2^* in the second period.*

CEOs do not have career concerns in the second period because the firm is dissolved at the end of this period. Hence, this proposition predicts that the preferences of CEOs who are closer to end of their careers to be more in line with the preferences of the shareholders. The results in the literature about changes in managers' behavior as their careers evolve are somewhat mixed. Avery and Chevalier (1999) argue that risk taking increases over time as the manager becomes more confident in her abilities. Chevalier and Ellison (1999), Hong, Kubik, and Solomon (2000), and Lamont (2002) provide some evidence for this. Prendergast and Stole (1996) argue the opposite, and Graham (1999), Menkhoff, Schmidt, and Brozynski (2006), and Boyson (2010) provide evidence in favor of this opposing view.

An obvious but important corollary of the above findings is that if the solution of the firm's maximization problem yields lower profits with $\tilde{\theta}$ than with $\bar{\theta}$, the firm fires the old CEO and hires a new one.[26] This leads to the optimal firing rule.

Corollary 1 (Optimal firing rule) *The firm fires the old CEO and hires a new one in the second period iff $\tilde{\theta} < \bar{\theta}$.*

This firing rule is consistent with Hirshleifer and Thakor (1994, 1998), Hermalin and Weisbach (1998, 2012), Adams and Ferreira (2007), and Bushman, Dai, and

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25. When $b_2 = 0$, the CEO is indifferent between any projects, including the optimally risky one. Thus, the firm wants to offer some stock in equilibrium.

26. The implicit assumption here is that the reservation payoff of the CEO, $\underline{u}$, remains unchanged despite the fact that beliefs about her type are updated based on the first-period output. In reality, this reservation payoff may adjust (see the arguments in Holmstrom, 1982/1999; and Gibbons and Murphy, 1992). Following Bushman, Dai, and Wang (2010), we assume for simplicity that there is downward rigidity in the reservation payoffs because managerial ability is firm specific and valuable only within the organization. Nonetheless, choosing an excessively risky project in equilibrium is possible even when reservation payoffs get updated in response to changes in beliefs about managerial ability. In such a case, a manager's future compensation is still an increasing function of firm's expectation about her ability, and as we show in the text, she can increase market's expectation about her ability by choosing an excessively risky project.

Wang (2010), in all of which the CEO is fired if the assessment about her ability is below a particular threshold. There is in fact an association between CEO turnover and their relative performance (Coughlan and Schmidt, 1985; Warner, Watts, and Wruck, 1988; Gibbons and Murphy, 1990; Murphy and Zimmerman 1993; Pourciau, 1993; Parrino, 1997; Defond and Park, 1999; Kaplan and Minton, 2012).

The First Period

This subsection shows the possibility that an excessively risky project is undertaken in the first period. The optimal firing rule that we derive in the previous subsection says that the firm keeps the old CEO if and only if $\tilde{\theta} \geq \bar{\theta}$. Thus, the CEO has an incentive to influence the market's belief in her ability by her project choice. This is in her best interest if the benefit of decreasing her layoff risk is greater than her loss from compensation due to choosing a project different from the optimally risky project.

We now derive the CEO's probability of being fired at the end of the first period, p. Because there are two types (high and low) and two states (good and bad) in the model, there are four possible state realizations for any given project choice. If the CEO chooses the optimally risky project with r_1^*, the firm infers her actual ability upon observing the output, unless by chance outputs coincide for this project choice in any two state realizations.[27] Then, high-ability CEOs are fired with probability zero while low-ability ones are fired with probability one. Given that each type is equally likely in the population, the *ex ante* probability of being fired is 1/2.

Similarly, for other project choices for which the firm infers the actual ability of the CEO upon observing the output (*i.e.,* the cases in which the outputs do not overlap for any state realization of the two types), high-ability CEOs are fired with probability zero while low-ability ones are fired with probability one. Then, once again, the ex ante probability of being fired is 1/2. This means that, given any positive amount of stock ownership, optimally risky project with r_1^* dominates any such project choice, because the CEO faces the same probability of being fired even when she chooses the optimally risky project but receives a higher first-period compensation by doing so.

So, which project does a CEO choose in equilibrium? To answer this, we need to consider three cases in terms of the difference between the abilities. The first case is

27. Because the optimally risky project's probability of failure is less than 1/2, the expectation about the CEO's ability will be below average when outputs coincide for the optimally risky project by chance. Then, the probability of being fired will be higher than 1/2.

the case in which even the bad-state output of a high-ability CEO is higher than the good-state output of a low-ability CEO for any project choice and so outputs cannot overlap. This occurs when $\theta_H - f(1) \geq \theta_L + f(1)$ or when the difference between the abilities is high (*i.e.*, $\theta_H - \theta_L \geq 2f(1)$). This is because if this inequality holds, then it should *strictly* hold for all $r_1 \in [0,1)$ as $f(\cdot)$ is an increasing function. In this case, the firm is able to infer the actual ability of a CEO for all possible output realizations, and thus the probability of being fired is independent of CEO's project choice and equal to 1/2. Then, again, given any positive amount of stock ownership, the optimally risky project with r_1^* dominates all other projects as it involves the same layoff risk with higher first-period compensation. The following lemma records this result.

LEMMA 3 (CASE 1) *When the difference between the abilities is high (i.e., $\theta_H - \theta_L \geq 2f(1)$), the CEO chooses the optimally risky project with $r_1^* < 1/2$, in equilibrium. Her probability of being fired is* $1/2$.

In the second case, the difference between the abilities is intermediate (*i.e.*, $2f(1/2) \leq \theta_H - \theta_L < 2f(1)$). Now, by choosing the project with $\bar{r}_1 = f^{-1}((\theta_H - \theta_L)/2)$, the CEO is able to overlap the bad-state output when she turns out to be a high-ability CEO with the good-state output when she turns out to be a low-ability CEO (*i.e.*, $\theta_H - f(\bar{r}_1) = \theta_L + f(\bar{r}_1)$). If the firm observes this "overlapped" output level, it is not certain about which type could have produced this output. Then, the conditional expectation on the type of the CEO is

$$E[\theta_i \mid y_1] = (1 - \bar{r}_1)\,\theta_L + \bar{r}_1\theta_H. \tag{5}$$

As a natural consequence of statistical inference, this conditional expectation increases as the project's probability of failure increases. Because $1/2 \leq f^{-1}((\theta_H - \theta_L)/2)$, we know that $\bar{r}_1 \geq 1/2$; this in turn implies $E[\theta_i \mid y_1] \geq \bar{\theta}$. Therefore, the firm keeps the CEO in the firm when it observes this overlapped output. Outputs do not coincide in the remaining state realizations, the CEO's type is perfectly inferred, and as a result the high-ability ones are retained while the low-ability ones are fired. Consequently, the probability of being fired is $p = \Pr\{\theta = \theta_L\} \times \Pr\{y_1 = \theta_L - f(\bar{r}_1)\} = \bar{r}_1/2$, which is definitely less than 1/2, the probability of being fired when the CEO chooses a different project, and so her type is inferred in all state realizations.

Choosing $\bar{r}_1$ minimizes the probability of being fired but it is not automatically an equilibrium. By choosing the excessively risky project rather than the optimally risky project, the CEO is minimizing her layoff risk in the second period, but, she is now offered lower compensation in the first period because she did not choose the optimally risky project. For now, we report the project with $\bar{r}_1$ as the project that minimizes the layoff risk, but later we derive the conditions under which choosing that project becomes an equilibrium.

LEMMA 4 (CASE 2) *When the difference between the abilities is intermediate (i.e.,* $2f(1/2) \leq \theta_H - \theta_L < 2f(1)$*), the probability of failure that minimizes the probability of being fired is equal to*

$$\bar{r}_1 = f^{-1}\left(\frac{\theta_H - \theta_L}{2}\right) \geq \frac{1}{2}, \tag{6}$$

which is associated with an excessively risky project. The CEO's resulting probability of being fired is $\bar{r}_1/2$*.*

Finally, in the third case, the difference between the abilities is low (*i.e.*, $0 < \theta_H - \theta_L < 2f(1/2)$). Let us first consider the interval $2f(0) < \theta_H - \theta_L < 2f(1/2)$. Following the reasoning we have in Case 2, we obtain (5) once again when the CEO chooses to overlap the outputs. However, this time $E[\theta_i \mid y_1] < \bar{\theta}$ in such a case. She keeps her job only when she turns out to be a high-ability CEO who lands in the good state. Thus, when she overlaps the outputs, her probability of being fired is $p = 1 - \Pr\{\theta = \theta_H\} \times \Pr\{y_1 = \theta_H + f(\bar{r}_1)\} = (1 + \bar{r}_1)/2$, which is higher than 1/2, the probability of being fired when she chooses a different project, and so the outputs do not overlap for any two state realizations. This suggests that in this case, given any positive amount of stock ownership, the optimally risky project with r_1^* dominates all other projects, including the one with $\bar{r}_1$.[28] In the remaining part of the interval of case 3 (*i.e.*, $0 < \theta_H - \theta_L \leq 2f(0)$) outputs do not match in any way and thus the probability of being fired cannot be any lower than 1/2, which implies that the CEO chooses the optimally risky project.

LEMMA 5 (CASE 3) *When the difference between the abilities is low (i.e.,*$0 < \theta_H - \theta_L < 2f(1/2)$*, the CEO chooses the optimally risky project with* $r_1^* < 1/2$*, in equilibrium. Her probability of being fired is* $1/2$*.*

In sum, the CEO chooses the optimally risky project in equilibrium when the difference between the abilities is high or low, but when the difference between the two abilities is intermediate she may choose a project at which the bad-state output of a high-ability CEO coincides with the good-state output of a low-ability CEO. This strategy minimizes her layoff risk. Of course, for this to be an equilibrium, it must also be in her best interest to do so, which we focus on next.

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28. If outputs match by chance for the optimally risky project, then the CEO chooses a project whose probability of failure is arbitrarily close to the one for the optimally risky project.

In the rest of this subsection, we analyze possible equilibrium project choices when the difference between the abilities is intermediate. According to Lemma 4, if the CEO chooses the excessively risky project with $\bar{r}_1$, then her probability of being fired is $\bar{r}_1/2$. If she chooses any other project, her probability of being fired is 1/2. Then, she is better off choosing the optimally risky project with r_1^* among all these possible projects because her probability of being fired is still 1/2 but her first-period compensation is higher. This means that the optimally risky project with r_1^* always dominates all other projects, except the excessively risky project with $\bar{r}_1$, given any positive amount of stock ownership. Thus, the CEO's choice in Case 2 is between the projects with $\bar{r}_1$ and r_1^* only.

The firm's maximization problem is the same as in the second period, except now it includes an additional constraint. If the firm wants the CEO to choose the optimally risky project, it must compensate the forgone expected payoff that comes from increased layoff risk by not choosing the project with $\bar{r}_1$. We call this constraint the *career concern constraint*, which is given by

$$E\left[w_1\left(a_1, b_1, y_1\left(\bar{\theta}, r_1^*\right)\right)\right] + \frac{\underline{u}}{2} \geq E\left[w_1\left(a_1, b_1, y_1\left(\bar{\theta}, \bar{r}_1\right)\right)\right] + \frac{(2-\bar{r}_1)\underline{u}}{2} \quad \text{if } r_1 \neq \bar{r}_1. \tag{CC}$$

The left-hand side of this constraint is the expected payoff of the CEO if she chooses the optimally risky project with r_1^* and the right-hand side is that if she chooses the excessively risky project with $\bar{r}_1$. This constraint is derived as follows. If the CEO chooses the excessively risky project with $\bar{r}_1$, her probability of keeping her job in the second period, in which she always obtains her reservation payoff $\underline{u}$, is $(2-\bar{r}_1)/2$. Therefore, her second-period expected payoff is $[(2-\bar{r}_1)\underline{u}]/2$ if she chooses the excessively risky project with $\bar{r}_1$ in the first period. Adding her expected first-period compensation to this term yields the right-hand side of the inequality. If she chooses the optimally risky project with r_1^*, the probability of keeping her job in the second period is 1/2; hence, her expected payoff is $\underline{u}/2$ in the second period. Adding her expected first-period compensation to this term yields the left-hand side of the inequality.

Reorganizing the career concern constraint after employing the linear compensation contract assumption gives

$$(1-2r_1^*)\, f\left(r_1^*\right) - (1-2\bar{r}_1)\, f\left(\bar{r}_1\right) \geq \frac{(1-\bar{r}_1)\,\underline{u}}{2b_1}. \tag{CC'}$$

This constraint shows that when the career concern is sufficiently strong, it may be stricter than the incentive compatibility constraint; thus, the solution may involve the excessively risky project with $\bar{r}_1$ chosen by the CEO as a result of the discontinuous jump created by her career concern. The next question is exactly when choosing the excessively risky project with $\bar{r}_1$ is better than choosing the optimally risky project with r_1^*, which we proceed to answer now. A necessary condition is that the firm prefers operating when the CEO chooses the excessively risky project with $\bar{r}_1$, which holds as long as $\underline{u} \leq \theta_L$, which we have already assumed.

There are two cases to consider in which excessively risky projects are undertaken in equilibrium. In the first, satisfying the career concern constraint and having the CEO choose the optimally risky project requires giving her stocks more valuable than the firm's output (*i.e.*, $b_1 > 1$), which the firm cannot afford without incurring a loss. Thus, in such a situation, the firm *involuntarily* allows the excessively risky project to be undertaken in equilibrium. If, therefore,

$$(1 - 2r_1^*) f(r_1^*) - (1 - 2\bar{r}_1) f(\bar{r}_1) < \frac{(1 - \bar{r}_1)\underline{u}}{2}, \tag{9}$$

then (CC') is satisfied only when $b_1 > 1$, which the firm cannot afford without incurring a loss, and thus we get the excessively risky project undertaken in equilibrium. This inequality represents a situation in which the CEO's career benefit from choosing the excessively risky project to hide her type is higher than the expected return from the project. In such a case, the firm cannot compensate the CEO for her career benefit from choosing the excessively risky project, even if it offers the whole first-period return to her. Note that all terms in this inequality are exogenous. Thus, if it holds, then (CC') cannot hold, and the excessively risky project becomes imperative.

In the second case in which there is an excessively risky project undertaken in equilibrium, having the CEO choose optimally risky project is less profitable than letting her choose excessively risky one. Thus, the firm *voluntarily* allows the excessively risky project to be undertaken in equilibrium.[29] This time, (CC') is satisfied, which requires providing an amount of stock ownership that satisfies $b_1 \geq (\underline{u}(1 - \bar{r}_1))/(2[(1 - 2r_1^*)f(r_1^*) - (1 - 2\bar{r}_1)f(\bar{r}_1)])$. Hence, the lowest possible stock compensation, $b_1 y_1(\bar{\theta}, r_1^*)$, is given by the following amount:

$$\Omega := \frac{\underline{u}(1 - \bar{r}_1)\left[\bar{\theta} + (1 - 2r_1^*) f(r_1^*)\right]}{2\left[(1 - 2r_1^*) f(r_1^*) - (1 - 2\bar{r}_1) f(\bar{r}_1)\right]}. \tag{10}$$

29. In a related vein, Bebchuk and Spamann (2010) also mentions that even after eliminating the excessive risk from the perspective of the common shareholders in banks, there may still remain excessive risk from the perspective of the society because common shareholders are not concerned about preferred shareholders, bondholders, depositors, and tax payers. We get our result for a different reason because we do not have any of these third parties in the model.

Then, if $(1-2r_1^*)f(r_1^*) - \Omega < (1-2\bar{r}_1)f(\bar{r}_1) - \underline{u}$, the firm voluntarily allows the CEO to choose the excessively risky project. The left-hand side of this inequality is the profit of the firm when the CEO chooses the optimally risky project and the right-hand side is that when she chooses the excessively risky one. Reorganizing it yields a condition that looks similar to (9):

$$(1-2r_1^*)\, f\,(r_1^*) - (1-2\bar{r}_1)\, f\,(\bar{r}_1) < \Omega - \underline{u}. \tag{11}$$

We summarize the above discussion in the following proposition.

PROPOSITION 5 (EXCESSIVELY RISKY PROJECT / TWO-TYPE) *Suppose that the difference between the abilities is intermediate (i.e., $2f(1/2) \leq \theta_H - \theta_L < 2f(1)$). The firm involuntarily allows the CEO to choose the excessively risky project if (9) holds. It voluntarily allows the CEO to choose the excessively risky project if (11) holds.*

The crucial point here is that choosing the excessively risky project is possible even under an optimal compensation contract. If the excessively risky project is undertaken, the optimal contract is given by $b_1 > 0$, and $a_1 = \underline{u} - b_1[\bar{\theta} + f(\bar{r}_1)(1-2\bar{r}_1)]$. In the involuntary case, as shown in (9), it is optimal for the CEO to choose the excessively risky project if the expected loss in output that arises from choosing the excessively risky project is less than the career benefit obtained from choosing it. In the voluntary case, as shown in (11), the benefit of choosing the optimally risky project is less than the cost of compensating the CEO to let her choose the optimally risky project.

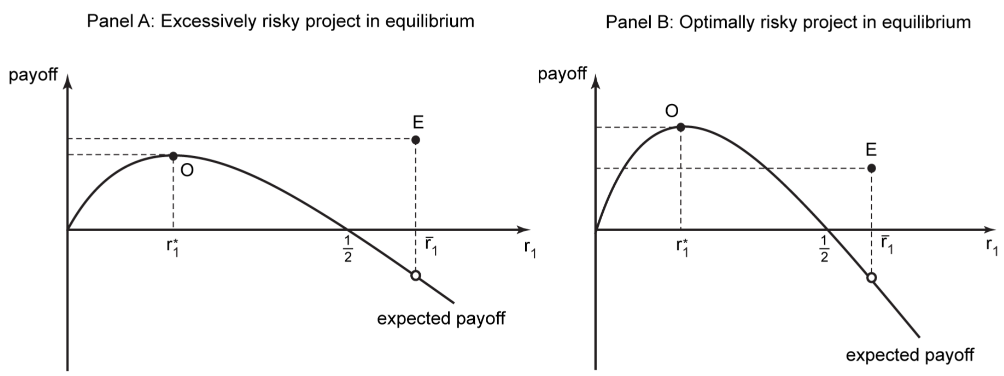

FIGURE II
Choosing an excessively or optimally risky project in equilibrium

Figure II provides a graphical intuition for choosing the excessively risky project. It shows the expected payoff of the CEO *from managerial action* for any r_1 level. Her payoff is increasing up to the optimal probability of failure r_1^* at point O, and then it is ever decreasing unless her career concern kicks in, which is where her payoff discontinuously jumps up to point E. If this point is above point O, as in Panel A, then the CEO finds it optimal to choose the excessively risky project. This is because the decrease in her first-period compensation due to not choosing the optimally risky project is less than the career benefit she obtains by minimizing her layoff risk by choosing the excessively risky project. However, if it turns out that point E is below point O, as in Panel B, the CEO chooses the optimally risky project. It is noteworthy that the excessively risky project with $\bar{r}_1$ means choosing a negative NPV project in terms of the return from managerial action. Thus, the project choice alone contributes negatively to the firm output in equilibrium, but the return from managerial ability absorbs the loss.[30]

We close this section with some comments on the structure of the model and robustness of the results under different specifications.

The fact that there is just one point jumping up discontinuously as a result of career concern in Figure II is an artifact of our two-type specification. Nevertheless, as we show in Section , the same mechanism works when we have a continuum of types, in which case there is a mass of points jumping up and their local maximizer gives us the new $\bar{r}_1$. If it is also the global maximizer (as in Panel A of Figure II), then the excessively risky project is chosen in equilibrium. Otherwise, the CEO chooses the optimally risky project (as in Panel B of Figure II).

Our main results are independent of bilateral risk neutrality. First, unlike the bilateral risk-neutrality case of a standard hidden action problem, the career concern can be so strong that even providing the output of the first period to the CEO may not prevent her from choosing the excessively risky project. The analogy would be a young fund manager who may choose excessively risky investments even in managing her own portfolio as a result of her concern that if she does not perform well now, she might not receive outside funds in the future. Second, as shown in the appendix, the results remain qualitatively the same even when the CEO is risk averse.

The CEO's possibility of affecting a firing decision with her project choice implies behavior consistent with behavioral finance's concept of CEO overconfidence. This literature is based on the hypothesis that many CEOs tend to think that they are better than the average (Malmendier and Tate 2005), and this leads them to be more likely to attribute good outcomes to their managerial ability or style. Hence,

30. Palomino and Prat (2003) provide a similar figure representing the set of risky portfolios. They mention that the textbook analysis shows only the increasing part of the figure as the decreasing part involves dominated strategies. However, those strategies are in fact chosen in their analysis as well as ours.

the literature argues that overconfident managers overestimate their abilities, so their investment decisions are riskier than is ideal. In our setting, a 'rational' CEO chooses an excessively risky project not because she is overestimating her ability, but to ensure that the market overestimates her ability.

In this simple two-type world, a bonus contract, which pays a fixed sum if the output is above a certain threshold, may in fact implement the optimally risky project. Suppose, for example, the firm promises to pay a fixed bonus equal to $\underline{u}$ if the CEO obtains $\theta_H + f(r_1^*)$, $\theta_H - f(r_1^*)$, $\theta_L + f(r_1^*)$, or $\theta_L - f(r_1^*)$ and zero otherwise. The CEO is still fired if her assessed ability is below average. While it is immediately clear that this contract implements the optimally risky project if the CEO cannot sabotage output, proving the same result when sabotaging output is possible requires some treatment.

When sabotaging output is possible, the CEO chooses the excessively risky project with $\mathring{r}_1$, which satisfies $\theta_L + f(\mathring{r}_1) = \theta_H - f(r_1^*)$. The probability of failure $\mathring{r}_1$ is higher than $\bar{r}_1$ defined in (6). If the CEO obtains $\theta_H + f(\mathring{r}_1)$, she can sabotage output (perhaps by selling it with too low a price) and make it appear as if she chose the optimally risky project with r_1^*. In this case, she not only gets the bonus in the first period but also keeps her job in the second period. If she obtains $\theta_H - f(\mathring{r}_1)$, then she cannot get the bonus, but she keeps her job in the second period because the firm infers that she is a high-ability CEO. If she obtains $\theta_L + f(\mathring{r}_1)$, the firm cannot be sure if she is a low-ability CEO in the good state or a high-ability CEO in the bad state. However, because $\mathring{r}_1 > \bar{r}_1$, it expects her type to be higher than $\bar{\theta}$ and thus keeps her in the firm in the second period. Moreover, because $\theta_L + f(\mathring{r}_1) = \theta_H - f(r_1^*)$, it pays the bonus. Finally, if she obtains $\theta_L - f(\mathring{r}_1)$, she cannot get the bonus and she is fired for sure. Consequently, her expected two-period benefit from choosing the excessively risky project with $\mathring{r}_1$ is $(1 - \mathring{r}_1)\underline{u} + (2 - \mathring{r}_1)\underline{u}/2$, while that from choosing the optimally risky project is $\underline{u} + \underline{u}/2$, which is higher. Thus, whether the CEO can sabotage output or not, the bonus contract implements the optimally risky project.

One can put forward this result as a remarkable argument supporting bonus contracts against excessive risk taking. After all, the common view in the media is that it is in fact these contracts that triggers excessive risk taking but this result says that they can in fact prevent it.[31] Though, one needs to be careful in coming to this conclusion from our model. The economic environment in the model is so simple that the firm learns quite a lot about the project choice simply by looking at the output. This disappears in a relatively more complex environment with idiosyncrasies while

31. This view has an impact in recent regulatory framework, too. For example, the American Recovery and Reinvestment Act prohibits TARP recipients from paying or accruing any bonus, but allows restricted stocks.

the mechanism we talk about (namely the motivation for choosing projects in order to minimize layoff risk) is still at work.

2.4 Continuum of Types Case

In this section, we extend the line of reasoning we derived from the two-type analysis to a continuum of CEO types. Our analysis also predicts an inverse U-shaped relationship between unobservable ability and the probability of being fired: while the above-average CEOs do not face any layoff risk, among the below-average CEOs, higher-ability ones are certainly fired while lower-ability ones are fired only with some probability.

The optimal firing rule, derived in Corollary 1, and the optimal second-period compensation contract, which gives the CEO her reservation payoff in the second period, continue to apply in this section. Thus, as in the two-type case, the basic mechanism of the model works as follows. Given that the CEO is paid her reservation payoff in the second period, she trades off the decrease in her layoff risk in the second period by choosing an excessively risky project in the first period for the increase in her expected compensation in the first period by choosing the optimally risky project. There are robust instances in which the former effect dominates the latter in expected payoff, and thus we get an excessively risky project chosen in equilibrium, either by the firm's consent or against its will.

We shall now talk about "the range of abilities" rather than "the difference between the two abilities," as there is now a continuum of abilities rather than just two. In particular, we assume that managerial abilities are uniformly distributed on the interval $[\theta_L, \theta_H]$ with mean $\bar{\theta}$. Just as in the two-type world, it turns out that there are three possible cases to consider in terms of the range of abilities (high, intermediate, and low), and we find that excessively risky projects undertaken in equilibrium only for the intermediate range of abilities. For brevity, we state only the results for the other two cases in the following lemma, leaving the detailed analysis to the appendix.

Lemma 6 (Cases 1 and 3) *When there is a high (i.e., $\theta_H - \theta_L \geq 4f(1)$) or low (i.e., $\theta_H - \theta_L < 2f(1/2)$) range of abilities in the CEO labor market, the CEO chooses the optimally risky project with $r_1^* < 1/2$, in equilibrium. Her probability of being fired is $1/2$.*

Now, consider Case 2 in which there is an intermediate range of abilities in the CEO labor market (*i.e.*, $2f(1/2) \leq \theta_H - \theta_L < 4f(1)$). This time, we proceed by the guess-and-verify method. We make the *educated* guess that the CEO chooses the project with $\bar{r}_1$ such that

$$4\bar{r}_1 f(\bar{r}_1) = \theta_H - \theta_L \tag{12}$$

is satisfied. This is the project choice that guarantees that even the worst type is able to overlap her good-state output with the bad-state output of an above-average CEO. The subsequent analysis proceeds as follows. Assuming the project with $\bar{r}_1$ to be the equilibrium project choice, we first derive the probability of being fired. Then, in the appendix , we prove that this project is indeed the one that minimizes the probability of being fired. Finally, we show that minimizing the probability of being fired can indeed be an equilibrium under certain conditions.

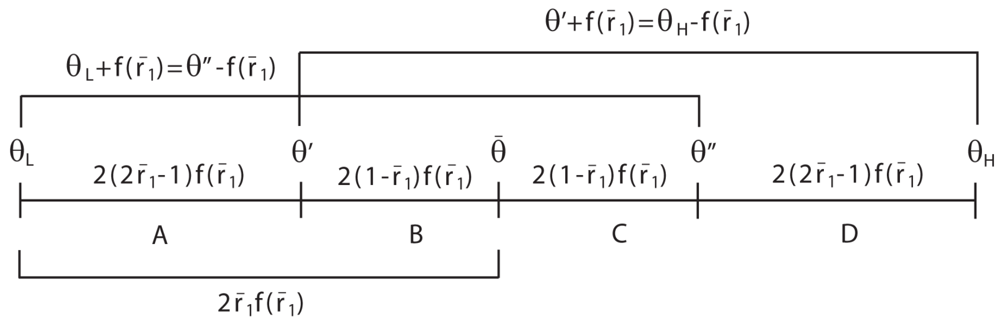

FIGURE III
The partition of CEO types in case 2

Figure III shows the partition of CEOs on the ability distribution. The partitions are denoted by A, B, C, and D. The ability range of this case guarantees that, given $\bar{r}_1$, there is a θ''-type whose bad-state output coincides with the good-state output of the worst type, θ_L, and the firm's expectation between these two types is exactly $\bar{\theta}$ (that is, $\theta_L + f(\bar{r}_1) = \theta'' - f(\bar{r}_1)$ and $(1-\bar{r}_1)\theta_L + \bar{r}_1\theta'' = \bar{\theta}$). They also guarantee that there is a θ'-type whose good-state output coincides with the bad-state output of the best type, θ_H (that is, $\theta' + f(\bar{r}_1) = \theta_H - f(\bar{r}_1)$). Of course, the expectation between these two types must be higher than $\bar{\theta}$.

Figure III provides the distance between the particular types mentioned in the previous paragraph. Eq. (12) implies that the distance between θ_L and $\bar{\theta}$ and the distance between $\bar{\theta}$ and θ_H are both $2\bar{r}_1 f(\bar{r}_1)$ because $\bar{\theta}$ is the mean of the uniform distribution. Moreover, from the specifications provided in the previous paragraph, one can easily find that the distance between $\bar{\theta}$ and θ'' is $2(1-\bar{r}_1)f(\bar{r}_1)$. Thus, the distance between θ'' and θ_H is $2(2\bar{r}_1 - 1)f(\bar{r}_1)$, which is also the distance between θ_L and θ'. Consequently, the mass in A is equal to the mass in D and the mass in B is equal to the mass in C. Note also that $\bar{r}_1$ is associated with an excessively risky project because it is higher than $1/2$ as a result of the fact that $4\bar{r}_1 f(\bar{r}_1) > 2f(1/2)$ in this case.

We can now derive the probability of being fired in each partition. Because the expectation between θ_L and θ'' is exactly $\bar{\theta}$ at $\bar{r}_1$, the expectation about the ability of a CEO in A must be higher than $\bar{\theta}$ when she obtains the good-state output. Thus, she is rehired in such an output realization. If she obtains the bad-state output, her ability is inferred and she is fired for certain. Thus, the probability of being fired for a CEO in this partition is $\bar{r}_1$. Next, consider a CEO in B. With the given project choice, she is not able to overlap her good-state output with the bad-state output of any existent type and yet her ability is less than $\bar{\theta}$; thus, she is certainly fired in any output realization.

Now consider a CEO in C. Her ability is inferred to be above $\bar{\theta}$ because there is no CEO below $\bar{\theta}$ overlapping her good-state output with the bad-state output of this CEO. Thus, she is rehired for certain. Finally, the bad-state output of a CEO in D coincides with the good-state output of a CEO in A, and thus she is rehired in her bad state. She is rehired for certain in her good state as well, because her output in that state does not coincide with the bad-state output of any existent type above her. Hence, the probability of being fired is zero for a CEO in this partition.

Given the above analysis, the overall probability of being fired is given by $p = \bar{r}_1 \times \Pr\{\theta \in A\} + 1 \times \Pr\{\theta \in B\} + 0 \times \Pr\{\theta \in C\} + 0 \times \Pr\{\theta \in D\}$, or

$$p = \bar{r}_1 \frac{2\left(2\bar{r}_1 - 1\right) f\left(\bar{r}_1\right)}{4\bar{r}_1 f\left(\bar{r}_1\right)} + \frac{2\left(1 - \bar{r}_1\right) f\left(\bar{r}_1\right)}{4\bar{r}_1 f\left(\bar{r}_1\right)} = \frac{2\bar{r}_1^2 - 2\bar{r}_1 + 1}{2\bar{r}_1}, \tag{13}$$

which is definitely less than $1/2$ because $\bar{r}_1 > 1/2$. What remains to be shown is that the project with $\bar{r}_1$ is indeed the one that minimizes the probability of being fired, which we prove in the appendix by comparing the p value in (13) with the ones that stem from other possible project choices. Thus, we have the following lemma.

Lemma 7 (Case 2) *When there is an intermediate range of abilities in the CEO labor market (i.e., $2f(1/2) \leq \theta_H - \theta_L < 4f(1)$), the probability of failure level that minimizes the probability of being fired solves (12), which is associated with an excessively risky project. The resulting probability of being fired is given by (13).*

In the rest of this section, we look for the equilibrium project choice in Case 2. As in the two-type case, the probability of failure of a project that solves (12) is not automatically an equilibrium. For that to be an equilibrium, minimizing the probability of being fired must be in the best interest of the CEO. This may be the case when the CEO's compensation benefit by choosing the optimally risky project is dominated in expected payoff by the career benefit she derives by choosing the excessively risky project and hence minimizing her probability of being fired. However, unlike the two-type case in which choosing the excessively risky project with $\bar{r}_1$ is the only serious alternative against the optimally risky project, here the CEO may potentially choose a project different from the one minimizing the probability of being fired in equilibrium.

As shown in the appendix, choosing a project with a probability of failure higher than $\bar{r}_1$, satisfying $f(r_1) \in (f(\bar{r}_1), 2\bar{r}_1 f(\bar{r}_1))$, results in a higher probability of being fired than choosing the project with $\bar{r}_1$. At the same time, because $\bar{r}_1$ is closer to r_1^*, the first-period compensation is going to be higher with any amount of stock-based compensation. Thus, choosing the project with $\bar{r}_1$ still dominates in expected payoff choosing any project satisfying $f(r_1) \in (f(\bar{r}_1), 2\bar{r}_1 f(\bar{r}_1))$. However, if the CEO chooses a project satisfying $f(r_1) \in (\bar{r}_1 f(\bar{r}_1), f(\bar{r}_1))$, as shown in the appendix, the probability of being fired is still higher than choosing the project with $\bar{r}_1$, yet this time the first-period compensation is going to be higher with any amount of stock-based compensation because this project's probability of failure is closer to r_1^*. As a result, the CEO may prefer to trade off the increased probability of being fired for higher first-period compensation. Any such project chosen in equilibrium is still excessively risky although it does not minimize the layoff risk. Therefore, unlike the two-type case, there are now many excessively risky projects in an interval that may be chosen in equilibrium rather than just one such project (*i.e.*, point E of Figure II). The local maximizer of this interval is the most serious candidate against the optimally risky project, and in fact, if it is also the global maximizer it is the equilibrium.

We now turn to the derivation of the optimal contract. The increase in the probability of being rehired in the second period by choosing the project with $\bar{r}_1$ in the first period is now given by

$$(1 - p(\bar{r}_1)) - (1 - p(r_1^*)) = \frac{3\bar{r}_1 - 2\bar{r}_1^2 - 1}{2\bar{r}_1}. \tag{14}$$

Thus, the new career concern constraint with $\bar{r}_1$ is given by

$$E\left[a_1 + b_1 y_1\left(\bar{\theta}, r_1\right)\right] - E\left[a_1 + b_1 y_1\left(\bar{\theta}, \bar{r}_1\right)\right] \geq \frac{\left(3\bar{r}_1 - 2\bar{r}_1^2 - 1\right)\underline{u}}{2\bar{r}_1} \quad \text{if } f(r_1) \notin (\bar{r}_1 f(\bar{r}_1), f(\bar{r}_1)), \tag{CC}$$

where the left-hand side is the extra compensation that the firm must provide to the CEO for her expected forgone career benefit by choosing a project with r_1 such that $f(r_1) \notin (\bar{r}_1 f(\bar{r}_1), f(\bar{r}_1))$, which is shown on the right-hand side. Apart from this change in the career concern constraint, the maximization problem of the firm and its solution remain qualitatively the same. Thus, we provide the following proposition without a proof.

PROPOSITION 6 (EXCESSIVELY RISKY PROJECT / CONTINUUM) *Suppose there is an intermediate range of abilities in the CEO labor market (i.e.,* $2f(1/2) \leq \theta_H - \theta_L < 4f(1)$*). The firm involuntarily allows the CEO to choose the excessively risky project if*

$$f(r_1^*)(1-2r_1^*) - f(\bar{r}_1)(1-2\bar{r}_1) < \frac{(3\bar{r}_1 - 2\bar{r}_1^2 - 1)\,\underline{u}}{2\bar{r}_1}. \qquad (15)$$

It voluntarily allows the CEO to choose the excessively risky project if

$$f(r_1^*)(1-2r_1^*) - f(\bar{r}_1)(1-2\bar{r}_1) < \frac{(3\bar{r}_1 - 2\bar{r}_1^2 - 1)\left[f(r_1^*)(1-2r_1^*) + \bar{\theta}\right]\underline{u}}{2\bar{r}_1\left[f(r_1^*)(1-2r_1^*) - f(\bar{r}_1)(1-2\bar{r}_1)\right]} - \underline{u}. \qquad (16)$$

In both cases, the equilibrium project choice with r_1 *satisfies* $f(r_1) \in (\bar{r}_1 f(\bar{r}_1), f(\bar{r}_1)]$*, where* $\bar{r}_1$ *is defined by (12).*

Eqs. (15) and (16) are respectively the counterparts of (9) and (11) in the continuum of types case. Note that if these equations hold for the project with probability of failure with $\bar{r}_1$ and if another project whose probability of failure satisfying $f(r_1) \in (\bar{r}_1 f(\bar{r}_1), f(\bar{r}_1)]$ dominates the project with $\bar{r}_1$, then these conditions hold for that project as well. Thus, the proposition applies for any project in that interval, not just for the one with $\bar{r}_1$. The intuitions for (15) and (16) are the same as those provided for Proposition 5. Eq. (15) says that the career benefit the CEO derives from choosing the excessively risky project is higher than the compensation benefit she derives in the first period by choosing the optimally risky project, even when she is offered the whole first-period return. Thus, the firm cannot design a linear compensation contract that implements the optimally risky project, even if it wants to do so. Eq. (16) gives the condition under which the expected profit of the firm is higher with the excessively risky project than that with the optimally risky one. As in the two-type case, one can easily see that none of our results stems from our assumption that the CEO is risk neutral.

So far, we have shown that all results of the two-type case extend to the continuum of types case. This case also provides an important prediction that we do not have in the two-type case. Consider a CEO whose ability is below $\bar{\theta}$ in Figure III. If she is in A, then she is able to overlap her good-state output with the bad-state output of an above-average CEO; thus she is not fired in such a state. However, if she is in B, then she is not able to overlap her good-state output with the bad-state output of any existent type in the ability distribution. As a result, a CEO in B is fired for certain whereas one in A is fired only with probability r_1, which means that, among those who are below average, a worse type is less likely to be fired than a better type. However, those who are in C and D, all of whom are above average, are not fired in any case. Thus, there is an inverse U-shaped relationship between unobserved ability and the probability of being fired.

PROPOSITION 7 (ABILITY AND LAYOFF RISK) *There is an inverse U-shaped relationship between the unobserved ability and the probability of being fired.*

The intuition for this result is as follows. By choosing a riskier project, a lower-ability CEO can disguise her type more convincingly because her good-state output is not going to be very high anyway. Hence, she has some chance of successfully substituting the return from managerial ability with the return from managerial action. The firm is skeptical to some extent, but it is not 100% sure if the CEO is below average ability or not. A higher-ability (but still below average) CEO is also able to do the same substitution, but this time the observed output is so high that the firm believes that there is no way that this CEO is above average ability. That is, if the CEO ends up with an unbelievably high output, then the firm is certain that this output is coming from a lucky below-average type who gambled and thus fires her without hesitation.

2.5 Asymmetric Information Case

This section relaxes our informational assumption by assuming that CEOs privately know their abilities in the two-type setting. Now that CEOs know their abilities, different types can choose different projects in equilibrium. The reservation payoff of a high-ability CEO is now u_H, which satisfies $u_H \leq \theta_H$, and that of a low-ability CEO is u_L, which satisfies $u_L \leq \theta_L$. It is natural to assume that $u_H > u_L$, considering that high-ability CEOs have higher outside options. We also make the following assumption, which rules out the possibility of separation in the second period.

ASSUMPTION 1 (NO SEPARATION) $\theta_H - \theta_L \geq 3(u_H - (u_L/2))$ *and* $\theta_L/\theta_H \geq u_L/u_H$.

The two expressions in this assumption ensure that the firm cannot offer a contract aimed only at the low- and high-ability CEOs, respectively.[32] Hence, knowing that CEOs have no career concerns in the second period, the firm offers a pooling

32. Unlike many asymmetric information problems, here the firm may want to attract only the low-ability CEOs because it may eliminate the moral hazard aspect of the problem. That is, the benefit of hiring a low-ability CEO (who is going to choose the optimally risky project) with a separating contract may outweigh the benefit of hiring a CEO (who will not choose the optimally risky project if she is a low-ability one) with a pooling contract.

compensation contract that attracts both types. In turn, both CEO types choose the optimally risky project in the equilibrium, and thus no agency problem arises in this period, as in the previous sections. Because a pooling contract is offered in the second period, the optimal firing rule derived in the symmetric-incomplete information model continues to hold in this information setting.

To show the possibility of an excessively risky project undertaken in equilibrium, we now turn to the analysis of the first period. Allowing for asymmetric information extensively enlarges the strategy space of the CEOs. In the two-type world, a CEO may choose to overlap the good-state output of a low-ability CEO with the bad-state output of a high-ability one. Now that she knows her own ability, she can even overlap good states with good states and bad states with bad states. We first show that the firm's expectation about the CEO's ability is higher than $\bar{\theta}$ in each of these cases. Thus, it is not *ex ante* clear which one is the best strategy for the CEO under various conditions.

LEMMA 8 (STRATEGIES) *Suppose that high-ability CEOs choose the optimally risky project with r_1^*. Consider a low-ability CEO.*

1. *If she chooses the project with $\bar{r}_1 \in [1 - r_1^*, 1)$, at which her good-state output overlaps with the bad-state output of a high-ability CEO (i.e., $\theta_L + f(\bar{r}_1) = \bar{y}_1 = \theta_H - f(r_1^*)$), then, upon observing such an output level, the firm's expectation about her ability is greater than or equal to $\bar{\theta}$. Her overall probability of being fired is $\bar{r}_1$.*

2. *If she chooses the project with r_1', at which her good-state output overlaps with the good-state output of a high-ability CEO, (i.e., $\theta_L + f(r_1') = y_1' = \theta_H + f(r_1^*)$), then, upon observing such an output level, the firm's expectation about her ability is greater than or equal to $\bar{\theta}$. Her overall probability of being fired is r_1'.*

3. *If she chooses the project with $\hat{r}_1$, at which her bad-state output overlaps with the bad-state output of a high-ability CEO (i.e., $\theta_L - f(\hat{r}_1) = \hat{y}_1 = \theta_H - f(r_1^*)$), then, upon observing such an output level, the firm's expectation about her ability is greater than or equal to $\bar{\theta}$. Her overall probability of being fired is $1 - \hat{r}_1$.*

The proof is in the appendix. It is obvious that a high-ability CEO is rehired for certain in the second period in any of the three cases of this lemma. Thus, she will in fact choose the optimally risky project with r_1^* because this maximizes her first-period compensation without affecting her probability of being fired.[33] However, a low-ability CEO's choice is among projects with $\bar{r}_1$, r_1', $\hat{r}_1$, and r_1^*, depending on the case.

The strategies defined in Lemma 8 are not always viable. First, none is viable when $\theta_H - f(r_1^*) \geq \theta_L + f(1)$, because in such a case, a low-ability CEO cannot overlap her output with the output of a high-ability CEO in any state. Second, as the first part of Lemma 8 suggests, the project with $\bar{r}_1$ is not an effective strategy for a low-ability CEO when $\bar{r}_1 \in [0, 1 - r_1^*)$, because it does not decrease her probability of being fired. Third, choosing a project with r_1' is a viable strategy only if $\theta_H + f(r_1^*) < \theta_L + f(1)$; otherwise, there exists no project with r_1' overlapping the good-state output of a low-ability CEO with that of a high-ability CEO. This requires $\theta_H - \theta_L \in (0, f(1) - f(r_1^*))$. Fourth, choosing a project with $\hat{r}_1$ is a viable strategy only if $\theta_L - f(0) > \theta_H - f(r_1^*)$; otherwise, there exists no project with $\hat{r}_1$ overlapping the bad-state output of a low-ability CEO with that of a high-ability CEO. This requires $\theta_H - \theta_L \in (0, f(r_1^*) - f(0))$.

The requirements in the above paragraph result in six different cases in terms of the difference between the abilities. For brevity, we consider only Case 2 here, in which an excessively risky project is undertaken in equilibrium, and leave the analysis of the remaining cases to the appendix. Case 2 is of particular interest because the CEO employs the same strategy of the previous sections in this case, namely overlapping the good-state output of a low-ability CEO with the bad-state output of a high-ability CEO by choosing the project with $\bar{r}_1$. However, choosing excessively risky projects is not limited to this case. In fact, there is another case (Case 4) in which low-ability CEOs may potentially overlap their good-state outputs with those of high-ability CEOs by choosing the excessively risky project with r_1'.[34]

In Case 2, $\theta_H - \theta_L \in [f(r_1^*) + f(1 - r_1^*), f(r_1^*) + f(1))$ and thus neither the project with r_1' nor the one with $\hat{r}_1$ is viable. Assume, for the moment, that a high-ability CEO chooses the optimally risky project with r_1^*. We know from the first part of Lemma 8 that the firm rehires the low-ability CEO if she chooses the project with $\bar{r}_1$ and overlaps her good-state output with the bad-state output of a high-ability CEO. Hence, the only serious candidate against choosing the project with r_1^* is choosing

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33. There is an exceptional measure-zero case in which the good-state output of low-ability CEOs coincides with the bad-state output of high-ability CEOs by chance for the optimally risky project (*i.e.*, $\theta_L + f(r_1^*) = \theta_H - f(r_1^*)$). In this case, as we show in Appendix (Case 6), a high-ability CEO chooses a project whose probability of failure is arbitrarily close (but not equal) to r_1^*.

34. In Case 4, low-ability CEOs may even overlap their bad-state outputs with that of high-ability CEOs by choosing the project with $\hat{r}_1$.

the one with $\bar{r}_1$ in this case. Now, consider a high-ability CEO. The firm keeps her if it observes the overlapped output. It keeps her even when she produces a different output, because her ability, which is high, is inferred. Thus, if she chooses the optimally risky project, her probability of being fired is zero regardless of her output, which means that she has no incentive to deviate from this project, as it will also maximize her first-period compensation. The firm needs to pay some positive amount of stock ownership to guarantee this, which it certainly does. This discussion results in the following lemma.

LEMMA 9 (CASE 2) *If $\theta_H - \theta_L \in [f(r_1^*) + f(1 - r_1^*),\ f(r_1^*) + f(1))$, then high-ability CEOs choose the optimally risky project with r_1^* in equilibrium and their probability of being fired is zero. Low-ability CEOs choose either the optimally risky project with r_1^*, in which case their probability of being fired is one, or the excessively risky project with $\bar{r}_1$ so that their good-state output coincides with the bad-state output of a high-ability CEO, in which case their probability of being fired is $\bar{r}_1$.*

We now show the possibility that an excessively risky project is undertaken in equilibrium. The firm hires just one CEO and therefore its contract offer must provide at least u_H if it wants to contract with a high-ability CEO. The first expression in Assumption 1 (*i.e.*, $\theta_H - \theta_L \geq 3(u_H - (u_L/2))$) ensures that attracting both types is better for the firm than attracting only the low-ability CEOs. The second expression in Assumption 1 (*i.e.*, $\theta_L/\theta_H \geq u_L/u_H$) ensures that if both types choose the optimally risky project, then any contract that satisfies the individual rationality constraint of a high-ability CEO also satisfies that of a low-ability CEO. If a low-ability CEO chooses the excessively risky project with $\bar{r}_1$, she does so because it makes her better off for all compensation schemes than choosing r_1^*. Consequently, if high-ability CEOs participate, low-ability CEOs will participate as well.

The career concern constraint of a low-ability CEO guarantees that the extra compensation that she gets by choosing the optimally risky project rather than that with $\bar{r}_1$ is higher than her career benefit by choosing the project with $\bar{r}_1$:

$$[a_1 + b_1\theta_L + b_1(1 - 2r_L) f(r_L)] - [a_1 + b_1\theta_L + b_1(1 - 2\bar{r}_1) f(\bar{r}_1)] \geq (1 - \bar{r}_1)\frac{[\theta_L + (1 - 2r_2^*) f(r_2^*)]\, u_H}{\theta_H + (1 - 2r_2^*) f(r_2^*)} \quad \text{if } r_L \neq \bar{r}_1. \quad \text{(CC)}$$

Here, $1 - \bar{r}_1$ that appears on the right-hand side is the probability that the CEO keeps her job and the remaining term is her expected compensation in the second period. Then, if

$$(1 - 2r_1^*) f(r_1^*) - (1 - 2\bar{r}_1) f(\bar{r}_1) < (1 - \bar{r}_1)\frac{[\theta_L + (1 - 2r_2^*) f(r_2^*)]\, u_H}{\theta_H + (1 - 2r_2^*) f(r_2^*)} \qquad (17)$$

is satisfied, the compensation contract cannot satisfy (CC) for all $a_1 \in \Re^+$ and $b \in [0,1]$, in which case a low-ability CEO chooses the project with $\bar{r}_1$ rather than the one with r_1^*. Because a high-ability CEO chooses the project with r_1^* and a low-ability one chooses the one with $\bar{r}_1$, the expected output of the firm is the same for all $b_1 \in (0,1]$, and hence the optimal compensation contract is the one that minimizes the compensation without violating the constraints. The following proposition summarizes our findings.

Proposition 8 (Excessively risky project / asymmetric information) *If $\theta_H - \theta_L \in [f(r_1^*) + f(1-r_1^*), f(r_1^*) + f(1))$ and (17) holds, then, in the pooling equilibrium, low-ability CEOs choose the excessively risky project with $\bar{r}_1$ while high-ability CEOs choose the optimally risky project with r_1^*.*

2.6 Conclusion

The project choice of a CEO who is concerned with her career may differ from the project choice that maximizes the shareholders' return or society's social return. The question is in what way the project choice will be distorted. The managerial conservatism literature suggests that a top manager is likely to be less entrepreneurial and take too little risk because she would like to oversee the firm with the least amount of problems and the minimum risk of obtaining bad states; thus this literature advises shareholders to design compensation contracts that encourage the manager to take higher risk.

In this paper, we show that CEOs layoff risk may lead them to employ excessively risky projects. The existence of limited liability or convex compensations schemes are the two common explanations for excessive risk taking. Thus, to highlight the new channel we offer in this paper, we allow for only linear combinations of fixed-wage and stock compensation and do not assume limited liability. We show that optimal linear compensation contracts may not be helpful in preventing CEOs from choosing excessively risky projects. Because a CEO is replaced by a new CEO if her expected ability is below average, in trying to limit her layoff risk, she chooses a project that can improve the market's belief about her ability. In our setting, this can be achieved with choosing an excessively risky project when the range of managerial abilities is neither too high nor too low. The CEO chooses the project with which the good-state output when she turns out to be a low-ability type coincides with the bad-state output when she turns out to be a high-ability type.

While the firm foresees that the CEO will choose an excessively risky project, once it observes the overlapped output level, it has to statistically infer that this is more likely to be the output of a high-ability CEO who is in the bad state than the output of a low-ability CEO who is in the good state, as the bad state is more likely with an excessively risky project. Although the firm is not fooled by the actions of the CEO, its expectation about the CEO's ability is that it is above average, despite the fact that each type is equally likely in the population.

Whether there is excessive or too little risk in the market is obviously a sector-specific question. A president of a university may opt for a quiet life while a surgeon may push for surgery even though it is not entirely necessary. We believe that the banking industry, or the financial sector in general, is an example of excessive risk taking. The structure of financial markets are so complicated that shareholders cannot entirely and precisely evaluate whether the observed return is due to the CEO's ability or to pure luck. Using financial derivatives, CEOs can simply gamble on anything and possibly improve the market's belief on their ability. For one reason or another, there is a mismatch between the preferences of shareholders and CEOs, and we believe that there always will be.

Risk-averse CEO

This appendix shows that the possibility of excessively risky project undertaken by the firm is not coming from the assumption of bilateral risk neutrality. Assume, for the sake of the argument, that the firm continues to be risk neutral but the CEO becomes risk averse, and we are in Case 2 of the two-type world. Then, the first-period maximization problem of the firm is

$$\max_{a_1,b_1,r_1} \bar{\theta} + (1-2r_1) f(r_1) - \left(a_1 + b_1 y_1\left(\bar{\theta}, r_1\right)\right)$$

$$s.t.$$

$$E\left[u\left(a_1 + b_1 y_1\left(\bar{\theta}, r_1\right)\right)\right] \geq \underline{u} \tag{IR}$$

$$r_1 \in \arg\max E\left[u\left(a_1 + b_1 y_1\left(\bar{\theta}, \hat{r}_1\right)\right)\right] \tag{IC}$$

$$E\left[u\left(a_1 + b_1 y_1\left(\bar{\theta}, r_1\right)\right)\right] - E\left[u\left(a_1 + b_1 y_1\left(\bar{\theta}, \bar{r}_1\right)\right)\right] \geq \frac{(1-\bar{r}_1)\underline{u}}{2} \quad \text{if } r_1 \neq \bar{r}_1, \tag{CC}$$

where the constraints are respectively the individual rationality, incentive compatibility, and career concern constraints; $u(\cdot)$ is a concave utility function; and

$$\begin{aligned} E\left[u\left(a_1 + b_1 y_1\left(\bar{\theta}, r_1\right)\right)\right] &= \frac{1-r}{2}\left[u\left(a_1 + b_1\left(\theta_L + f(r_1)\right)\right) + u\left(a_1 + b_1\left(\theta_H + f(r_1)\right)\right)\right] \\ &+ \frac{r}{2}\left[u\left(a_1 + b_1\left(\theta_L - f(r_1)\right)\right) + u\left(a_1 + b_1\left(\theta_H - f(r_1)\right)\right)\right]. \end{aligned} \tag{A-1}$$

When $b_1 = 0$, then we have $E[u(a_1+b_1y_1(\bar{\theta}, r_1))] = u(a_1)$ for all $r_1 \in [0,1]$. Thus, (CC) is not satisfied when $b_1 = 0$. Now, assume that

$$E[u\left(y\left(\bar{\theta}, \tilde{r}_1\right)\right)] - E[u\left(y\left(\bar{\theta}, \bar{r}_1\right)\right)] < \frac{(1-\bar{r}_1)\underline{u}}{2}, \tag{A-2}$$

where $\tilde{r}_1$ is the probability of failure that maximizes the CEO's first-period payoff. This inequality means that (CC) cannot be satisfied when $a_1 = 0$ and $b_1 = 1$. Then, it cannot be satisfied for all $b_1 \in [0,1]$, either, because $E[u(a_1 + b_1y_1(\bar{\theta}, r_1))]$ is a continuous function. Thus, the excessively risky project is chosen whenever (A-2) is satisfied.

Proof of Lemma 6

Case 1 ($\theta_H - \theta_L \geq 4f(1)$): Let us consider each possible $r_1 \in [0,1]$ in turn. If $r_1 = 0$, then the output will be $\theta + f(0)$ for certain, in which case the firm infers the ability of the CEO from the output. Thus, she is fired only when it turns out that her ability is less than $\bar{\theta}$, which implies a probability of being fired of 1/2. Similarly, if $r_1 = 1$, then the output will be $\theta - f(1)$ for certain, and once again the firm perfectly infers the ability, which implies a probability of being fired of 1/2. If the CEO chooses a project with $r_1 \in (0, 1)$, then there must be two (interior) types θ' and θ'' such that the good-state output realization of the θ'-type coincides with the bad-state output realization of the θ''-type (*i.e.*, $\theta' + f(r_1) = \theta'' - f(r_1)$), and the firm's expectation about the CEO's ability after observing this output is $\bar{\theta}$ (*i.e.*, $(1 - r_1)\theta' + r_1\theta'' = \bar{\theta}$). Then, one can easily find that $\theta' = \bar{\theta} - 2r_1 f(r_1)$ and $\theta'' = \bar{\theta} + 2(1 - r_1)f(r_1)$ for any $r_1 \in (0, 1)$.

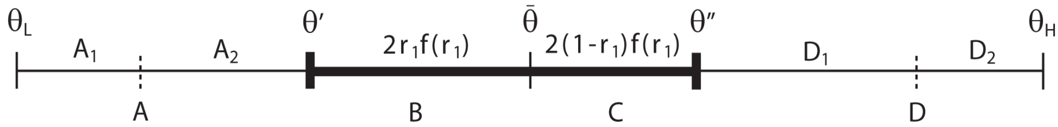

Figure IV
The partition of CEO types in case 1

Figure IV shows the partition of CEOs on the ability distribution when the chosen project's probability of failure is $r_1 \in (0, 1)$. Because $\theta_H - \theta_L \geq 4f(1)$, one can easily show that $\bar{\theta} - 2f(r_1) > \theta_L$, which implies that the mass of CEOs in A is larger than that in C. Thus, there is a subpartition of $A = A_1 \cup A_2$ such that the mass in A_2 is equal to the mass in C and A_1 is the residual partition. Similarly, one can show that $\bar{\theta} + 2f(r_1) < \theta_H$ for all $r_1 \in (0, 1)$ and thus the mass of CEOs in D is higher than that in B. Hence, there is a subpartition of $D = D_1 \cup D_2$ such that the mass in D_1 is equal to the mass in B and D_2 is the residual partition.

Given r_1, the good-state output realization of a CEO in A_1 coincides with the bad-state output realization of a below-average CEO, which means that the expectation about her ability is always lower than $\bar{\theta}$ regardless of the state. However, given r_1, the bad-state output realization of a CEO in D_2 does not coincide with the good-state output realization of any below-average CEO. Thus, the expectation about her ability is always higher than $\bar{\theta}$ regardless of the state.

We can now derive the probability of being fired in each partition. If the CEO is in A_1, then she is fired for certain because the firm knows that her ability is below average for any output realization. On the other hand, if the CEO is in A_2, her good-state output coincides with the bad-state output of a CEO in C. If she is in the bad state, the firm infers that her ability is less than $\bar{\theta}$ and fires her. If she is in the good state, the firm still fires her, because the expectation of θ' matching with θ'' is $\bar{\theta}$ and thus the expectation of any $\theta \in A_2$ matching with any $\theta \in C$ must be lower than $\bar{\theta}$.

If the CEO is in B, her good-state output coincides with the bad-state output of a CEO in D_1 and the expectation about her ability is higher than $\bar{\theta}$, which means that she is not fired in case of the good state. However, she is fired if she is in the bad state, as the firm infers that her ability must be less than $\bar{\theta}$. Thus, her probability of being fired is r_1 if she is in this partition. Next, consider a CEO in C. Her bad-state output coincides with that of a CEO in A_2 and thus her expected ability is less than $\bar{\theta}$, which means that she is fired in such a state. Otherwise, she is in the good state in which case her ability is inferred to be higher than $\bar{\theta}$ and thus the firm keeps her for certain. Thus, the probability of being fired in this partition is also r_1.

Now consider a CEO in D_1. The bad-state output realization of a CEO in this partition coincides with the good-state output realization of one in B, and the expectation about her ability is higher than $\bar{\theta}$, which means that she is not fired in such a state. She is not fired even when she is in the good state because the firm infers that her ability is higher than $\bar{\theta}$. Thus, a CEO in D_1 is rehired for certain. Finally, a CEO in D_2 is also rehired for certain, because, as previously argued, her ability is perfectly inferred.

Given the above analysis, the overall probability of being fired is given by $p = 1 \times \Pr\{\theta \in A\} + r_1 \times \Pr\{\theta \in B\} + r_1 \times \Pr\{\theta \in C\} + 0 \times \Pr\{\theta \in D\}$, or

$$p = \frac{\bar{\theta} - \theta_L - 2r_1 f(r_1)}{\theta_H - \theta_L} + r_1 \frac{2r_1 f(r_1)}{\theta_H - \theta_L} + r_1 \frac{2(1 - r_1) f(r_1)}{\theta_H - \theta_L} = \frac{1}{2}. \tag{A-3}$$

Because the CEO faces the same probability of being fired for any project choice, she chooses the optimally risky project with r_1^* as it is the best choice in terms of her first-period compensation, as long as she is given some stock ownership. Thus, she chooses the optimally risky project in equilibrium.

Case 3 ($\theta_H - \theta_L < 2f(1/2)$): If $\theta_H - \theta_L \leq 2f(0)$, outputs do not match in any case and thus the probability of being fired cannot be lower than 1/2. Now, consider the remaining part of the interval (*i.e.,* $2f(0) < \theta_H - \theta_L < 2f(1/2)$). This time, one can easily obtain (13) once again by going through exactly the same calculations as in Case 2. Yet, this time, $\theta_H - \theta_L = 4\bar{r}_1 f(\bar{r}_1) < 2f(1/2)$ which implies $\bar{r}_1 < 1/2$. Therefore, we have $p = 1/2$, which means that the minimum probability of firing for any project choice is not less than the one with the optimally risky project with r_1^*. But, then, because r_1^* is both the probability of failure level that maximizes the first-period compensation and the probability of failure level that minimizes the probability of being fired, the project associated with it is the equilibrium project choice.

The Probability of Being Fired with a Continuum of Types

This appendix shows that the guessed project choice with $\bar{r}_1$ of Case 2 of the continuum of types is indeed the project choice that minimizes the probability of being fired. We prove this claim in two steps. In the first step, we show that the probability of being fired is higher for any $r_1 \in [0, \bar{r}_1)$ than the one with $\bar{r}_1$. In the second step, we prove the same thing for any $(\bar{r}_1, 1]$.

Step 1: Show that $p(r_1) > p(\bar{r}_1)$ for all $r_1 \in [0, \bar{r}_1)$.

Subcase *i*: Suppose that the project's probability of failure satisfies $f(r_1) = \bar{r}_1 f(\bar{r}_1) < f(\bar{r}_1)$. Then, there must be a θ'-type and a θ''-type such that the good-state output of the θ'-type coincides with the bad-state output of the θ''-type, and thus $\theta' = \theta_L + 2(1 - r_1)f(r_1)$ and $\theta'' = \theta' + 2f(r_1)$, and the expectation about them is $(1 - r_1)\theta' + r_1\theta'' = \bar{\theta}$.

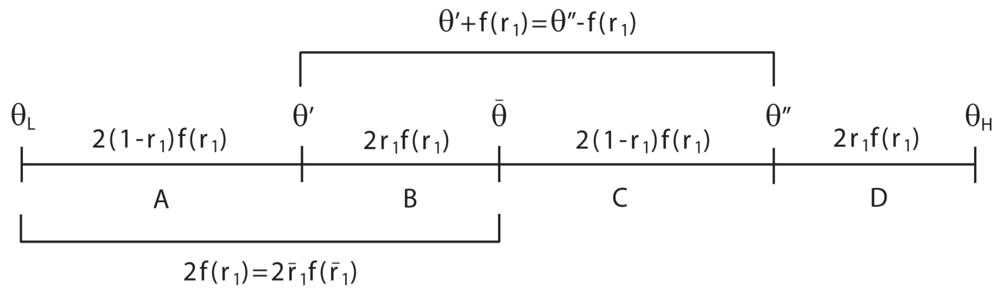

FIGURE V
The partition of CEO types in case 2 (subcase *i* of step 1)

Figure V portrays the subcase. Note that the mass in A is equal to the mass in C, and the mass in B is equal to the mass in D. It is easy to see that the probability of being fired is one in A, r_1 in B and C, and zero in D. Therefore, the overall probability of being fired is

$$p(r_1) = \frac{2(1 - r_1) f(r_1)}{4f(r_1)} + \frac{2r_1 f(r_1)}{4f(r_1)} = \frac{1}{2}, \tag{A-4}$$

which is obviously higher than $p(\bar{r}_1)$.

Subcase *ii*: Suppose that the project's probability of failure satisfies $f(r_1) < \bar{r}_1 f(\bar{r}_1) < f(\bar{r}_1)$. Then, there must be a θ'-type and a θ''-type such that the good-state output of the θ'-type coincides with the bad-state output of the θ''-type, and thus $\theta' = \theta_L + 2\bar{r}_1 f(\bar{r}_1) - 2r_1 f(r_1)$ and $\theta'' = \theta' + 2f(r_1)$, and the expectation about them is $(1 - r_1)\theta' + r_1\theta'' = \bar{\theta}$.

Figure VI portrays the subcase. Unlike Subcase *i*, in this subcase, the mass in A is larger than the mass in C because $2\bar{r}_1 f(\bar{r}_1) > 2f(r_1)$ and hence $2\bar{r}_1 f(\bar{r}_1) -$

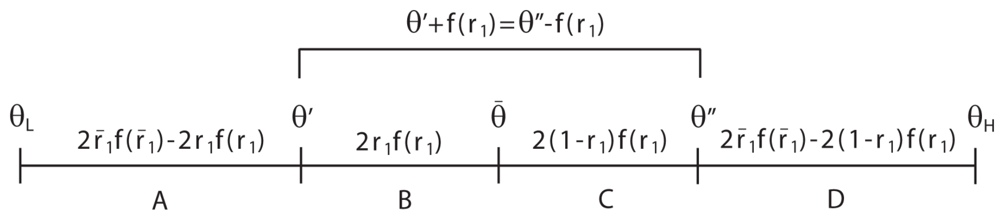

FIGURE VI
The partition of CEO types in case 2 (subcase *ii* of step 1)

$2r_1 f(r_1) > 2(1-r_1)f(r_1)$. For the same reason, $2\bar{r}_1 f(\bar{r}_1) - 2(1-r_1)f(r_1) > 2r_1 f(r_1)$ and hence the mass in D is larger than the mass in B. It is easy to see that the probability of being fired is one in A, r_1 in B and C, and zero in D. Therefore, the overall probability of being fired is

$$\frac{2\bar{r}_1 f(\bar{r}_1) - 2r_1 f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} + r_1 \frac{2f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} = \frac{1}{2}, \tag{A-5}$$

which is obviously higher than $p(\bar{r}_1)$.

Subcase *iii*: Suppose that the project's probability of failure satisfies $\bar{r}_1 f(\bar{r}_1) < f(r_1) < f(\bar{r}_1)$. Then, there must be a θ'-type, a θ''-type, a θ'''-type, and a θ''''-type such that $\theta' = \bar{\theta} - 2r_1 f(r_1)$, $\theta'' = \theta_H - 2f(r_1)$, $\theta''' = \theta_L + 2f(r_1)$, and $\theta'''' = \bar{\theta} + 2(1-r_1)f(r_1)$, as shown in Figure VII. Then, the mass in A is equal to the mass in E, the mass in C is equal to the mass in D, and the mass in B is equal to the mass in F. Then, it is easy to see that the probability of being fired is one in A and C, r_1 in B and E, and zero in D and F.

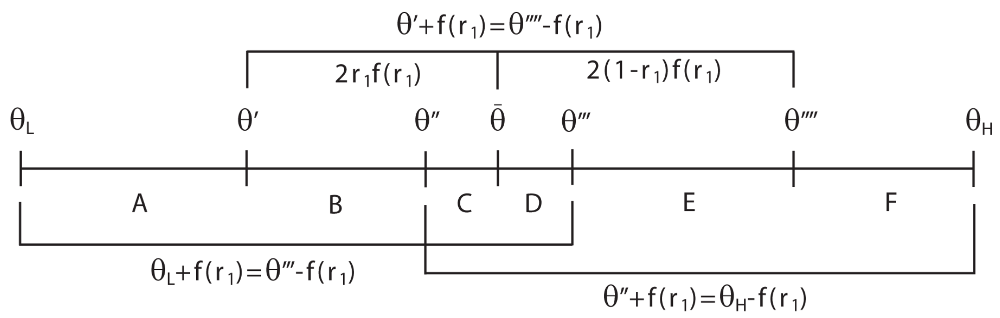

FIGURE VII
The partition of CEO types in case 2 (subcase *iii* of step 1)

The probabilities of being fired in each partition are given by

$$\Pr\{\theta \in A\} = \Pr\{\theta \in E\} = \frac{2\bar{r}_1 f(\bar{r}_1) - 2r_1 f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} \tag{A-6}$$

$$\Pr\{\theta \in B\} = \Pr\{\theta \in F\} = \frac{2\bar{r}_1 f(\bar{r}_1) - 2(1-r_1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} \tag{A-7}$$

$$\Pr\{\theta \in C\} = \Pr\{\theta \in D\} = \frac{2f(r_1) - 2\bar{r}_1 f(\bar{r}_1)}{4\bar{r}_1 f(\bar{r}_1)}. \tag{A-8}$$

Therefore, the overall probability of being fired is

$$\begin{aligned} p(r_1) &= \frac{2\bar{r}_1 f(\bar{r}_1) - 2r_1 f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} + r_1 \frac{2\bar{r}_1 f(\bar{r}_1) - 2(1-r_1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} \\ &\quad + \frac{2f(r_1) - 2\bar{r}_1 f(\bar{r}_1)}{4\bar{r}_1 f(\bar{r}_1)} + r_1 \frac{2\bar{r}_1 f(\bar{r}_1) - 2r_1 f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} \\ &= \frac{4r_1\bar{r}_1 f(\bar{r}_1) - 2(2r_1 - 1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)}. \end{aligned} \tag{A-9}$$

The CEO follows this strategy if she can decrease her probability of being fired to a level less than 1/2 by doing so:

$$\frac{4r_1\bar{r}_1 f(\bar{r}_1) - 2(2r_1 - 1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} < \frac{1}{2} \tag{A-10}$$

or $2r_1\bar{r}_1 f(\bar{r}_1) - (2r_1 - 1)f(r_1) < \bar{r}_1 f(\bar{r}_1)$. This is satisfied when $(2r_1 - 1)[\bar{r}_1 f(\bar{r}_1) - f(r_1)] < 0$, or $r_1 > 1/2$. Now, we need to show that this probability of being fired is higher than $p(\bar{r}_1)$. It is so if

$$\frac{4r_1\bar{r}_1 f(\bar{r}_1) - 2(2r_1 - 1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} > \frac{2\bar{r}_1^2 - 2\bar{r}_1 + 1}{2\bar{r}_1}, \tag{A-11}$$

or $(4r_1\bar{r}_1 - 4\bar{r}_1^2 + 4\bar{r}_1 - 2)f(\bar{r}_1) > 2(2r_1 - 1)f(r_1)$. Because $f(\bar{r}_1) > f(r_1)$, this holds when $4r_1\bar{r}_1 - 4\bar{r}_1^2 + 4\bar{r}_1 - 2 > 2(2r_1 - 1)$, or $(1 - \bar{r}_1)(\bar{r}_1 - r_1) > 0$, which is always satisfied. Thus, $p(r_1) > p(\bar{r}_1)$. This completes the proof of the claim that that $p(r_1) > p(\bar{r}_1)$ for all $r_1 \in [0, \bar{r}_1)$.

Step 2: Show that $p(r_1) > p(\bar{r}_1)$ for all $r_1 \in (\bar{r}_1, 1]$.

Subcase *i*: Suppose that the project's probability of failure satisfies $f(\bar{r}_1) < f(r_1) = (\theta_H - \theta_L)/2$. Then, the good-state output of the worst type coincides with the bad-state output of the best type, $\theta_L + f(r_1) = \theta_H - f(r_1)$. This means that $\theta + f(r_1) > \theta_H - f(r_1)$ for all $\theta \in (\theta_L, \bar{\theta})$. Thus, the firm infers the ability of the CEO when it observes any output level different from the overlapped output level, and thus fires the CEO with probability 1/2. If it observes the overlapped output level, it fires the CEO with probability $r_1/2$. Thus, the overall probability of being fired is approximately 1/2 and definitely higher than $p(\bar{r}_1)$.

Subcase *ii*: Suppose that the project's probability of failure satisfies $f(\bar{r}_1) < (\theta_H - \theta_L)/2 < f(r_1)$. Then, we have $\theta + f(r_1) > \theta_H - f(r_1)$ for all $\theta \in [\theta_L, \bar{\theta})$, which means that the output realization perfectly signals the ability of a CEO. Thus, the overall probability of being fired is 1/2, which is higher than $p(\bar{r}_1)$.

Subcase *iii*: Suppose that the project's probability of failure satisfies $f(\bar{r}_1) < f(r_1) < (\theta_H - \theta_L)/2$. Then, there must be a θ'-type and a θ''-type such that $\theta' = \theta_H - 2f(r_1)$ and $\theta'' = \theta_L + 2f(r_1)$, as shown in Figure VIII. The good-state output of the θ_L-type (θ'-type) coincides with the bad-state output of the θ''-type (θ_H-type). However, the expectation for both pairs is above $\bar{\theta}$. It is easy to see that the probability of being fired is r_1 in A, one in B, and zero in C and D.

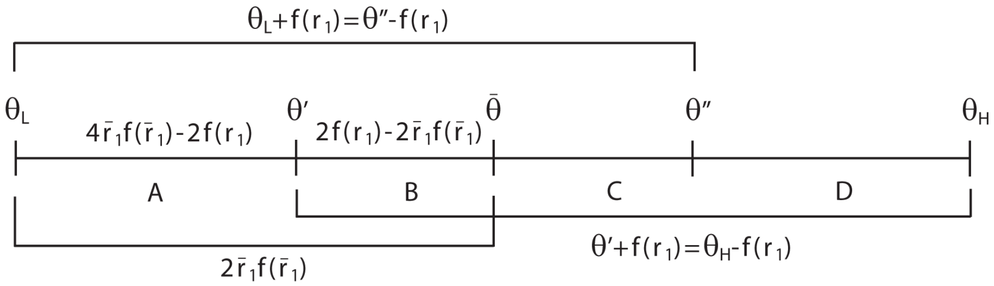

FIGURE VIII
The partition of CEO types in case 2 (subcase *iii* of step 2)

The overall probability of being fired is given by

$$p(r_1) = r_1 \frac{4\bar{r}_1 f(\bar{r}_1) - 2f(r_1)}{4\bar{r}_1 f(\bar{r}_1)} + \frac{2f(r_1) - 2\bar{r}_1 f(\bar{r}_1)}{4\bar{r}_1 f(\bar{r}_1)} \tag{A-12}$$

$$= \frac{2(2r_1 - 1)\bar{r}_1 f(\bar{r}_1) + 2(1 - r_1) f(r_1)}{4\bar{r}_1 f(\bar{r}_1)}. \tag{A-13}$$

Remember that

$$p(\bar{r}_1) = \frac{2(2\bar{r}_1 - 1)\bar{r}_1 f(\bar{r}_1) + 2(1 - \bar{r}_1) f(\bar{r}_1)}{4\bar{r}_1 f(\bar{r}_1)}. \tag{A-14}$$

Thus, $p(r_1) > p(\bar{r}_1)$ if $2(2r_1 - 1)\bar{r}_1 f(\bar{r}_1) + 2(1 - r_1)f(r_1) > 2(2\bar{r}_1 - 1)\bar{r}_1 f(\bar{r}_1) + 2(1 - \bar{r}_1)f(\bar{r}_1)$, which boils down to $4(r_1 - \bar{r}_1)\bar{r}_1 f(\bar{r}_1) + 2(1 - r_1)f(r_1) - 2(1 - \bar{r}_1)f(\bar{r}_1) > 0$. Because $f(\bar{r}_1) < f(r_1)$, let $f(r_1) = f(\bar{r}_1) + \lambda$ where $\lambda \geq 0$. Then, we have $4(r_1 - \bar{r}_1)\bar{r}_1 f(\bar{r}_1) + 2(1 - r_1)(f(\bar{r}_1) + \lambda) - 2(1 - \bar{r}_1)f(\bar{r}_1) > 0$. This boils down to $2(r_1 - \bar{r}_1)(2\bar{r}_1 - 1)f(\bar{r}_1) + 2\lambda(1 - r_1) > 0$, which always holds because $\bar{r}_1 > 1/2$. Hence, $p(r_1) > p(\bar{r}_1)$. This completes the proof of the claim that $p(r_1) > p(\bar{r}_1)$ for all $r_1 \in (\bar{r}_1, 1]$.

Proof of Lemma 8

1. When the firm observes $\bar{y}_1$, its expectation about the ability of the CEO will be

$$E[\theta_i \mid \bar{y}_1] = \left(\frac{1-\bar{r}_1}{r_1^* + 1 - \bar{r}_1}\right)\theta_L + \left(\frac{r_1^*}{r_1^* + 1 - \bar{r}_1}\right)\theta_H. \tag{A-15}$$

This is greater than or equal to $\bar{\theta} = (1/2)\theta_L + (1/2)\theta_H$ iff $(1-\bar{r}_1)/(r_1^*+1-\bar{r}_1) \le 1/2$, which holds for all $\bar{r}_1 \in [1-r_1^*, 1)$. Therefore, the firm keeps her in such a state, which happens with probability $1-\bar{r}_1$; otherwise she is fired, which happens with probability $\bar{r}_1$.

2. When the firm observes y_1', its expectation about the ability of the CEO will be

$$E[\theta_i \mid y_1'] = \left(\frac{1-r_1'}{1-r_1^* + 1 - r_1'}\right)\theta_L + \left(\frac{1-r_1^*}{1-r_1^* + 1 - r_1'}\right)\theta_H, \tag{A-16}$$

This is greater than or equal to $\bar{\theta} = (1/2)\theta_L + (1/2)\theta_H$ if $(1-r_1')/(1-r_1^*+1-r_1') \le 1/2$, which holds when $r_1' \ge r_1^*$. Note that $f(r_1') - f(r_1^*) = \theta_H - \theta_L > 0$ in this case. Hence, $f(r_1') > f(r_1^*)$, which implies that $r_1' > r_1^*$. Therefore, the firm keeps her in such a state, which happens with probability $1-r_1'$; otherwise she is fired, which happens with probability r_1'.

3. When the firm observes $\hat{y}_1$, its expectation about the ability of the CEO will be

$$E[\theta_i \mid \hat{y}_1] = \left(\frac{\hat{r}_1}{r_1^* + \hat{r}_1}\right)\theta_L + \left(\frac{r_1^*}{r_1^* + \hat{r}_1}\right)\theta_H, \tag{A-17}$$

This is greater than or equal to $\bar{\theta} = (1/2)\theta_L + (1/2)\theta_H$ if $(\hat{r}_1)/(r_1^*+\hat{r}_1) \le 1/2$, which holds when $\hat{r}_1 \le r_1^*$. Note that $f(r_1^*) - f(\hat{r}_1) = \theta_H - \theta_L > 0$ in this case. Hence, $f(r_1^*) > f(\hat{r}_1)$, which implies that $\hat{r}_1 < r_1^*$. Therefore, the firm keeps her in such a state, which happens with probability $\hat{r}_1$; otherwise she is fired, which happens with probability $1-\hat{r}_1$.

Cases under Asymmetric Information

As Lemma 8 suggests, in trying to minimize the probability of being fired, the CEO can choose three possible projects associated with three possible probabilities of failure: $\bar{r}_1$, r_1', and $\hat{r}_1$. The motivation of a low-ability CEO in choosing these projects is to disguise her type with her project choice. If one of these does not work or current compensation dominates career concern, the CEO chooses the optimally risky project with r_1^*. We have already derived the following feasibility conditions in the text. First, none of the strategies is viable when $\theta_H - f(r_1^*) \ge \theta_L + f(1)$ because in such a case a low-ability CEO cannot overlap her output with the output of a high-ability CEO in any state. This forms the lower boundary of Case 1 below.

Second, as the first part of Lemma 8 suggests, choosing a project with $\bar{r}_1$ is not an effective strategy for a low-ability CEO when $\bar{r}_1 \in (0, 1 - r_1^*)$ because it does not decrease her probability of being fired. This forms the lower boundary of Case 2 below.

Third, choosing a project with r_1' is a viable strategy only if $\theta_H + f(r_1^*) < \theta_L + f(1)$; otherwise there exists no r_1' overlapping the good-state output of a low-ability CEO with that of a high-ability CEO. This requires $\theta_H - \theta_L \in (0, f(1) - f(r_1^*))$. Fourth, choosing a project with $\hat{r}_1$ is a viable strategy only if $\theta_L - f(0) > \theta_H - f(r_1^*)$; otherwise there exists no $\hat{r}_1$ overlapping the bad-state output of a low-ability CEO with that of a high-ability CEO. This requires $\theta_H - \theta_L \in (0, f(r_1^*) - f(0))$. This condition and the previous one overlap, but both of these conditions are under the lower boundary of Case 2, $f(r_1^*) + f(1 - r_1^*)$.[35] Depending on the technology, the maximum of these two conditions form the lower boundary of Case 3 below and the minimum of them forms the upper boundary of Case 4. There is also the exceptional (and measure zero) case in which $\theta_H - f(r_1^*) = \theta_L + f(r_1^*)$ by chance, which is Case 6. Below, we state all these conditions and analyze them one by one.

Case 1 ($\theta_H - \theta_L \in [f(r_1^*) + f(1), \infty)$): In this case, $\theta_H - \theta_L$ is so high that a low-ability CEO is unable to overlap even her good-state output with the bad-state output of a high-ability CEO even when she chooses the project which is sure to fail (*i.e.*, $\theta_H - f(r_1^*) \geq \theta_L + f(1)$). This implies that a high-ability CEO's output when she chooses the optimally risky project is higher than a low-ability CEO's output for any project choice. This means that the outputs of different types cannot overlap, $y_1(\theta_H, r_1^*) > y_1(\theta_L, r_1)$, for all $r_1 \in [0, 1]$ in all states. Thus, if the high-ability CEO chooses a project with r_1^*, then the firm infers her ability at the end of the period. As a result, neither a high-ability CEO nor a low-ability one has career concerns, which means that they choose the optimally risky project with r_1^* in the first period since it maximizes their first-period compensation. Note that the firm needs to pay some positive amount of stock ownership to guarantee this.

LEMMA 10 (CASE 1) *If $\theta_H - \theta_L \in [f(r_1^*) + f(1), \infty)$, then both types choose the optimally risky project with r_1^* in equilibrium. Outputs do not overlap in any state combination and thus the firm infers the type of the CEO at the end of the first period. It fires the low-ability CEOs and rehires the high-ability ones.*

Case 2 ($\theta_H - \theta_L \in [f(r_1^*) + f(1 - r_1^*), f(r_1^*) + f(1))$**):** We analyze this case in the text.

35. $f(r_1^*) + f(1 - r_1^*)$ is trivially higher than $f(r_1^*) - f(0)$. The concavity of the risk-return function implies that $f(r_1^*) + f(1 - r_1^*) > f(1)$, and hence $f(r_1^*) + f(1 - r_1^*) > f(1) - f(r_1^*)$ must hold as well.

Case 3 ($\theta_H - \theta_L \in [\max\{f(1) - f(r_1^*), f(r_1^*) - f(0)\}, f(r_1^*) + f(1 - r_1^*))$): The analysis of this case is trivial because none of the projects with $\bar{r}_1$, r_1', or $\hat{r}_1$ is viable in this case. Hence, the type of a CEO will be inferred anyway and her probability of being fired will be independent of her project choice. Consequently, she chooses the optimally risky project in order to maximize her first-period compensation. Note that the firm needs to pay some positive amount of stock ownership to guarantee this.

LEMMA 11 (CASE 3) *If $\theta_H - \theta_L \in [\max\{f(1) - f(r_1^*), f(r_1^*) - f(0)\}, f(r_1^*) + f(1 - r_1^*))$, then both types of CEOs choose the optimally risky project with r_1^* in equilibrium. Outputs do not overlap in any state combination and thus the firm infers the type of the CEO at the end of the first period. It fires the low-ability CEOs and rehires the high-ability ones.*

Case 4 ($\theta_H - \theta_L \in [\min\{f(1) - f(r_1^*), f(r_1^*) - f(0)\}, \max\{f(1) - f(r_1^*), f(r_1^*) - f(0)\})$): The analysis of this case is also trivial. If $f(1) + f(0) > 2f(r_1^*)$, then overlapping her good-state output with that of a high-ability CEO is optimal for a low-ability CEO and thus she chooses a project with r_1'. If, however, $f(1) + f(0) < 2f(r_1^*)$, then overlapping her bad-state output with that of a high-ability CEO is optimal for a low-ability CEO, and thus she chooses a project with $\hat{r}_1$. Because a high-ability CEO is always rehired, she does not have career concerns and chooses the optimally risky project to maximize her first-period compensation. These are the projects that minimize the probability of being fired, not necessarily the equilibrium choices. If minimizing the probability of being fired is not optimal, a low-ability CEO chooses the optimally risky project with r_1^*. The probability of failure r_1' is higher than the probability of failure r_1^* of the optimally risky project but the managerial action-return function may have positive or negative NPV depending on whether the probability of failure is above or below 1/2.

LEMMA 12 (CASE 4) *If $\theta_H - \theta_L \in [\min\{f(1) - f(r_1^*), f(r_1^*) - f(0)\}, \max\{f(1) - f(r_1^*), f(r_1^*) - f(0)\})$, then a high-ability CEO chooses the optimally risky project with r_1^* in equilibrium and rehired for certain in the second period. A low-ability CEO minimizes her probability of being fired by choosing the excessively risky project with r_1' if $f(1) + f(0) > 2f(r_1^*)$ and overlap her good-state output realization with the good-state output realization of a high-ability CEO. In this case, she is fired with probability r_1'. She minimizes her probability of being fired by choosing the project with $\hat{r}_1$ if $f(1) + f(0) < 2f(r_1^*)$ and overlaps her bad-state output realization with the bad-state output realization of a high-ability CEO. In this case, the firm rehires the high-ability CEO while it fires the low-ability CEO with probability $1 - \hat{r}_1$.*

Case 5 $(\theta_H - \theta_L \in (0, \min\{f(1) - f(r_1^*), f(r_1^*) - f(0)\}))$**:** If a low-ability CEO chooses a project with r_1', her probability of being fired is r_1'; if she chooses a project with $\hat{r}_1$, her probability of being fired is $1 - \hat{r}_1$. Hence, the CEO chooses a project with r_1' or $\hat{r}_1$ in order to minimize her probability of being fired. We know that $\theta_L + f(r_1') = \theta_H + f(r_1^*)$ and $\theta_L - f(\hat{r}_1) = \theta_H - f(r_1^*)$. Thus, $r_1' \geq 1 - \hat{r}_1$ if and only if

$$f^{-1}\left(\theta_H - \theta_L + f\left(r_1^*\right)\right) + f^{-1}\left(\theta_L - \theta_H + f\left(r_1^*\right)\right) \geq 1. \tag{A-18}$$

However, it might be the case that the CEO still chooses the project with r_1' if her compensation benefit in the first period overweighs her career benefit in expected payoff. However, it turns out that this is not the case. The compensation of a low-ability CEO is weakly higher with $\hat{r}_1$ than with r_1'. If the firm offers a fixed wage, then evidently her compensations under both project choices are equal. Suppose that the firm offers a positive amount of stock ownership. Combining $\theta_L + f(r_1') = \theta_H + f(r_1^*)$ and $\theta_L - f(\hat{r}_1) = \theta_H - f(r_1^*)$ gives $|f(\hat{r}_1) - f(r_1^*)| = |f(r_1') - f(r_1^*)|$, and because the risk-return function is concave, this implies $|\hat{r}_1 - r_1^*| < |r_1' - r_1^*|$. We know that the expected return is a continuous and concave function in its positive range and that it is maximized at r_1^*. Thus, expected return decreases as we move away from the r_1^*. As a result, the expected return is always higher under $\hat{r}_1$ than it is under r_1'. Hence, if a positive amount of stock ownership is offered, then the current compensation is higher under $\hat{r}_1$ than it is under r_1'. This means that we get a project whose probability of failure is less than that of the optimally risky one undertaken in equilibrium.

LEMMA 13 (CASE 5) *If $\theta_H - \theta_L \in (0, \min\{f(1) - f(r_1^*), f(r_1^*) - f(0)\})$, then a high-ability CEO chooses the optimally risky project with r_1^* whereas a low-ability CEO chooses the project with $\hat{r}_1$ as long as (A-18) is satisfied. In this case, the low-ability CEO overlaps her bad-state output with the bad-state output of a high-ability CEO, and the firm rehires the high-ability CEO while it fires the low-ability CEO with probability $1 - \hat{r}_1$.*

This lemma is a sufficiency condition for choosing the project with $\hat{r}_1$. If (A-18) is not satisfied, whether the CEO chooses a project with $\hat{r}_1$ or r_1' depends on the exact trade-off between layoff risk and current compensation. As a matter of fact, the choice between a project with $\hat{r}_1$ and a project with r_1' is very sensitive to the technology. For example, if the managerial action-return function is linear, then probability of being fired with r_1' is lower than that with $\hat{r}_1$ and the first-period compensation is same for both project choices. Hence, a project with r_1' would certainly dominate a project with $\hat{r}_1$.

Case 6 $(\theta_H - \theta_L = 2f(r_1^*))$**:** This is a knife-edge case in which $\theta_L + f(r_1^*) =$

$\breve{y}_1 = \theta_H - f(r_1^*)$. When the firm observes $\breve{y}_1$, its expectation about the type of the CEO will be $E[\theta_i \mid \breve{y}_1] = r_1^*\theta_H + (1 - r_1^*)\theta_L$, which is less than $\bar{\theta}$ because $r_1^* < 1/2$. Therefore, the firm fires the CEO after such an observation. It fires the CEO even when it observes $y(\theta_L, r_1^*) \neq \breve{y}_1$ in which case her ability is inferred. Thus, she has no career incentive, which means that she chooses a project with r_1^* in the first period as it maximizes her first-period compensation. However, by differentiating her output from the output of a low-ability CEO, a high-ability CEO can decrease her probability of being fired from r_1^* to zero. As a result, the high-ability CEO will choose a project whose probability of failure is arbitrarily close (but not equal to) r_1^*. These are the projects that minimize the probability of being fired, not necessarily the equilibrium project choices. If minimizing the probability of being fired is not optimal, she chooses the optimally risky project with r_1^*.

LEMMA 14 (CASE 6) *If $\theta_H - f(r_1^*) = \theta_L + f(r_1^*)$, low-ability CEOs take the optimally risky project with r_1^* whereas high-ability CEOs choose a project whose probability of failure is arbitrarily close (but not equal to) r_1^*. Outputs do not overlap in any state combination and thus the firm infers the type of the CEO at the end of the first period. It fires the low-ability CEOs and rehires the high-ability ones.*

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