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QUANTITATIVE ECONOMICS OF CORPORATE CRIME,

PUNISHMENT, AND SOLUTION – *REGBONDS*

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NANYANG BUSINESS SCHOOL

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Statement of Originality

I hereby certify that the work embodied in this thesis is the result of original research, is free of plagiarised materials, and has not been submitted for a higher degree to any other University or Institution.

24 September 2019

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This thesis **does not** contain any materials from papers published in peer-reviewed journals or from papers accepted at conferences in which I am listed as an author.

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Summary

Managers engage in gray project investments (i.e. investment projects which have an ambiguous underlying legality). Many research has been conducted to understand the impact of such investments as well as the externalities arising from these investments. However, limited research has been done on providing a better understanding on why managers choose to engage in gray project investments. This thesis serves to shed light on the decision-making process of managers when it comes to gray project investments. Specifically, this thesis focuses on the quantitative economic incentives and provide intriguing insights that are grounded in firm mathematical models. The results help to explain certain real-world behavior by managers on gray project investments. This thesis also provides a novel solution – the *Regbonds* – that can potentially mitigate the level of gray project investments in the macro-economy. In the micro-setting, *Regbonds* are able to mitigate agency problems which helps to align the interests between shareholders and managers. Finally, I do hope that the thesis can help us better understand the underlying nature of gray project investments and the *Regbonds* can help to mitigate the real-world problems associated with these investments. This thesis consists of three chapters, the abstract for each chapter is as follows.

First chapter:

Our paper provides a novel model that analyzes firm's investments in gray projects. The paper then provides multiple extensions to the basic model to help researchers gain a better understanding of firm's behavior in the real-world in terms of gray investment projects. We then show that some form of collusion actually leads to a lower aggregate gray project investment due to a self-policing effect. We also show that a "ratting out" system commonly used by regulators might increase the aggregate gray project investment in the economy. For our intertemporal analysis, our results call for the importance of government intervention in the free market. We show that if a firm has been left alone for a sufficiently long period of time with no external shock to the system, the firm will eventually increase her gray project investment and will continue to do so for all later time periods. One way to ensure this does not happen is to have the regulators shock the system via direct intervention. Finally, in our business-friendly regulations setting, we also document that business-friendly regulations can help to reduce the optimal level of gray project investments by firms. We also conduct data analyses that provide empirical support for our Propositions.

Summary (continued)

Second chapter:
This paper is based on the idea of gray project investments and provides a basic model to allow decision makers to better understand the underlying characteristics of gray project investments. This paper then takes a step further at the macro-level and shows that there exists overinvestments of gray projects at the aggregate level. Furthermore, information asymmetry results in an inefficient allocation of deterrence investments by regulators. This paper presents a novel solution, the Regbonds. We show that Regbonds help to reduce aggregate gray project investments under the mandated setting by helping firms internalize the external costs of decision making. We also show that under the voluntary setting, Regbonds function as a signaling mechanism. This allows for a more efficient allocation of deterrence investments by regulators and helps to bring aggregate gray project investments closer towards optimal.

Third chapter:
We incorporate agency problem into the gray project investments model. We model this with risk preferences and compensation ratio. This allows us to see that gray project investment decreases and increases in the relative risk aversion parameter and compensation ratio parameter, respectively. We conduct data analysis on a testable hypothesis of our model and obtain supportive empirical evidence which lends credence to our model. Our paper focuses on the micro level and shows that Regbonds can help shareholders identify the underlying risk preference of managers and take corrective and preventive actions under the ex-post and ex-ante settings, respectively. Furthermore, we show that under certain conditions, Regbonds can better align interests between shareholders and managers in terms of gray project investments. This ensures the investments in gray projects undertaken by managers will be close to the exact level preferred by shareholders, with no over or under investment problems (i.e. manager-optimal is equivalent to firm-optimal gray project investments).

Firm's Optimal Gray Project Investments

Abstract

Our paper provides a novel model that analyzes firm's investments in gray projects. The paper then provides multiple extensions to the basic model to help researchers gain a better understanding of firm's behavior in the real-world in terms of gray investment projects. We then show that some form of collusion actually leads to a lower aggregate gray project investment due to a self-policing effect. We also show that a "ratting out" system commonly used by regulators might increase the aggregate gray project investment in the economy. For our intertemporal analysis, our results call for the importance of government intervention in the free market. We show that if a firm has been left alone for a sufficiently long period of time with no external shock to the system, the firm will eventually increase her gray project investment and will continue to do so for all later time periods. One way to ensure this does not happen is to have the regulators shock the system via direct intervention. Finally, in our business-friendly regulations setting, we also document that business-friendly regulations can help to reduce the optimal level of gray project investments by firms. We also conduct data analyses that provide empirical support for our Propositions.

1. Introduction

Becker (1968) published a seminal paper on crime and punishment by providing an economic model that sheds light on criminal behavior and decision-making. This triggered a wave of literature in criminal behavior within the field of economics and has provided useful insights to the legislative and judicial branch of the government in combatting against crimes at the individual level. Crimes are broadly divided into violent and non-violent crimes where punishments for the former tend to outweigh the latter (Bisogno et al., 2015; Izzi, 2018).

Corporate crimes are considered non-violent crimes, coupled with the notion where the financial industry has boomed in recent decades, this has led to a similar increase in financial crimes. Regulators have attempted to combat against this problem by increasing the amounts of regulations against such financial crimes. However, research for corporate crime has largely assumed that corporate crime fall under the same umbrella as traditional crime, with most papers extending that of Becker (1968). Thus far, we have seen Simpson (2002) that has differentiated between corporate and traditional crime. In addition, Holt (2018) and Freilich & Newman (2018) analyzed the interaction between law enforcers and the firm's criminal behavior. However, the analyses behind both strands of literature are largely qualitative with limited quantiative and empirical backing. After a thorough literature review, as in section 2, we have yet to document any comprehensive mathematical models that analyzed the decision making behavior of firms when it comes to investing in gray projects, an investment that can potentially be illegal and constitute as a corporate crime. [1]

This paper sheds insights on the characteristic of gray investment projects. We provide a basic framework to analyze the behavior of firms' investments in gray projects under different settings, specifically under a (i) multi-firm setting, (ii) multi-period setting, and (iii) business-friendly regulations setting. The purpose is to provide a tractable framework that allows researchers to quantify the real-world underlying investment behavior of firms when it comes to gray project investments.

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[1] Refer to section 3.1 for detailed definition of gray investment project.

We also compare the difference in the optimal amount of gray project investment in a monopoly against a competitive market and a collusive market. We show that some form of collusion actually leads to a lower aggregate gray project investment due to a self-policing effect. We also show that a "ratting out" system commonly used by regulators might increase the aggregate gray project investment in the economy.

For our intertemporal analysis, on the one hand, we show the condition that will see a firm increase their gray project investment in the subsequent time period. Furthermore, we show that meeting this condition will guarantee that the firm will meet this condition again in the subsequent time period. On the other hand, we also show the condition that will lead the firm to decrease their gray project investment in the subsequent time period. We show that meeting this condition does not guarantee that the condition will be met in the subsequent time period. Furthermore, we provide a proxy for regulators to test if the condition is being met. Taken together, our results call for the importance of government intervention in the free market. We show that if a firm has been left alone for a sufficiently long period of time with no external shock to the system, the firm will eventually increase her gray project investment and will continue to do so for all later time periods. One way to ensure this does not happen is to have the regulators shock the system via direct intervention. In addition, we document that common factors such as returns on investments, imposed penalty and parameter "g" (where parameter "g" is defined in section 3.1 to be the probability that an investment project turns out to be illegal) does not affect the firm's decision on the optimal amount of gray project investment in the subsequent period.

Finally, in our business-friendly regulations setting (i.e., the regulator invests in nurturing an ecosystem that is more business-friendly for entrepreneurs), we continue to document the importance of an active regulator. We showed that an active regulator that invests in making regulations more business friendly can not only reduce the excess returns on gray investment projects. It can also result in a lower optimal amount of gray project investment in the ecosystem. We further conduct data analyses that lend empirical credence to our Propositions.

The rest of the paper is organized as follows. Section 2 is the literature review. Section 3 lays out the basic model set-up. Section 4 conducts the analyses under a (i) multi-firm setting, (ii) multi-period, and (iii) business-friendly regulations setting. Section 5 conducts the empirical analyses. Section 6 concludes.

2. Literature Review

Becker (1968) wrote a seminal paper on crime and punishment by developing an economic model that determined optimal policies that minimize criminal behavior by individuals. In essence, he proposed that an individual commits an offence only if the expected utility to him exceeds the utility he could achieve by spending his time and resources at other activities. Block & Heineke (1975) expanded on the paper by accounting for multi-attributes of choice among individuals and argued that empirical determination is required to provide useful policy recommendations.

Furthermore, Becker (1968) proposed that a key deterrent for individual crime is a function of the severity of penalty and probability of conviction. This led many papers that focused on these two aspects with conflicting arguments on which is a better deterrent for crimes. For example, Grogger (1991) found that a higher certainty of punishment was more significant in deterring criminal activities. This was supported by Myers Jr. (1983) who documented that increases in the severity of punishment are weakly related to participation in crime; increases in certainty of punishment are positively related to participation in crime while higher wages have a strong and consistent deterrent effect on crime. Ehrlich (1973) found support for the hypothesis that the law-enforcement activity has a deterrent effect on offenders, independent of any preventive effect of imprisonment and makes a case for equalizing training and earning opportunities across person, independent of ethical considerations or any social welfare function. Tittle & Rowe (1974) provided support for the deterrent argument and suggested that certainty of punishment must achieve a critical level before an effect on crime rate can be observed. On the other hand, Witte (1980) found that certainty deters more than severity for relatively minor offenders (such as larceny and liquor sales) but when it comes to more serious offenses (such as assaultive or drug use offenses), she found that severity deters more than

certainty of punishment. Garoupa (1997) argued that more severe punishment deters crime in the long-run but can have a rather small impact in the short-run. Ehrlich (1975) also provided support for the severity argument by showing that capital punishment (i.e. death sentence) reduces murder rates. Ehrlich (1996) argued that punishment and other general incentives indeed exert a deterrent effect on offenders and suggested a direction of reform on the criminal justice system. Cornwell & Trumbull (1994) then argued that earlier analyses failed to control for observed heterogeneity in the dataset and that after controls are made, deterrent effects of arrest and conviction probabilities are much smaller than recorded by earlier analysis; this implies that the effectiveness of law enforcement incentives are overstated. Finally, Andreoni (1991) argued that traditional models assume an independence between penalty and probability of conviction but in reality, when the judicial system is built on the "reasonable doubt" test, the two factors are no longer independent.

The aforementioned research focuses on the individual level. Bringing this to the institutional level, Simpson (2002) argued that a company's choice to engage in misconduct is the same as any other business decision, where the potential loss due to its detection is weighted against its potential economic gain. In addition, Holt (2018) and Freilich & Newman (2018) undertook a comprehensive analysis on the interaction between law enforcers and the firm's criminal behavior. However, the analyses behind both strands of literature are largely qualitative with limited quantiative and empirical backing.

Individual crimes, relative to corporate crimes, tend to receive more attention from scholars until recently when the occurrence of the financial crises that occurred in the past couple of decades have led to more empirical papers that analyzed the underlying relationship between corporate crime, behavior and various aspects of firm performance. Specifically, the financial penalties and credit crisis associated with the financial crisis are considered consequences associated with gray project investments made within the financial sector. For example, Köster & Pelster (2017) found a significant negative relationship between financial penalty and pre-tax profitability with no significant relationship between the former and post-tax profitability as financial penalties are tax-deductible, and also a positive relation between financial penalty and bank stock

performance. Fich & Shivdasani (2007) found that following a financial fraud lawsuit, outside directors do not face abnormal turnover on the board of the sued firm but experience a significant decline in other board seats held and that fraud-affiliated directors are more likely to lose directorships at firms with stronger corporate governance and their departure is associated with valuation increases for these firms. Fahlenbrach & Stulz (2011) found that a lack of alignment of bank CEO incentives with shareholder interests cannot be blamed for the credit crisis or for performance of banks during the crisis as they found that banks with better alignment of incentives performed worse during the 2007/08 credit crisis. Hoshi, Kashyap, & Scharfstein (1990) provided support for the idea that financial distress is costly due to difficulty in renegotiation between firms and their creditors. Dermiguc-Kunt, Detragiache, & Merrouche (2013) showed that a stronger capital positions was associated with better stock market performance during the crisis but prior to the crisis, differences in capital did not have much impact on stock returns. Houston & James (1995) found little evidence that compensation policies in banking are designed to encourage excessive risk taking while Bhagat, Brickley, & Coles (1994) found that bargaining among firm claimants during a suit leads to very inefficient outcomes. Bizjak & Coles (1995) found that upon filing of suits, defendants experience significant wealth losses that are million dollars larger than wealth gains of plaintiffs and argued that financial distress, behavioral constrains and follow-on suits are some sources of wealth leakages. Fahlenbrach, Prilmeier, & Stulz (2012) found that a bank's stock return performance during the 1998 crisis predicts its stock return performance and probability of failure during the 2007/08 crisis. Finally, Agrawal, Jaffe, & Karpoff (1999) found little evidence that firms suspected or charged with fraud have unusually high turnover among senior managers or directors. These papers analyzed the impacts on firms that have been caught for engaging in corporate crime but failed to explain the underlying decision making process of these firms when they decided to invest in gray projects. Our paper provides the tools for researchers to better understand the firm's decision making process. In accounting literature, Dye & Sridhar (2004) modelled multidimensional report manipulation. Larcker & Zakolyukina (2012) found that a portfolio formed with firms with the highest deception scores from CFO narratives produced an annualized alpha of between −4% and −11%. Khanna, Palepu, & Srinivasan (2004) documented that cross-border economic interactions are associated with

similarities in disclosure and governance practices and that being associated with the U.S. tends to be associated with improved disclosure practices. These literature are more specific to the accounting and finance literature, while our papers provides a more general model that can be applied to not only the accounting and finance literature, but other types of industries as well.

In terms of making the punishment fit the crime, Stigler (1970) proposed that society must forego "complete" enforcement of the law simply because enforcement is costly, and society will provide a budget for the enforcement agencies that dictate a much lower level of enforcement. Davis (1983) argued for a retributive principle for setting statutory penalties and it appears to be morally preferred when it differs from the penalty derived from the utilitarian principle. Karpoff & Lott (1993) showed that relatively small amounts of corporate fines on firms committing fraud is sufficient as the external effects of such frauds are usually small. Furthermore, reputational penalty that the firm bears is large and constitutes most of the cost incurred by firms accused or convicted of fraud. Finally, Barth, Caprio, & Levine (2004) found that policies that rely excessively on direct government supervision and regulation of bank activities should raise a cautionary flag. They further suggested that compulsory information disclosure, empower private sector corporate control of banks and foster incentives for private agents to exert corporate control work best to promote bank development, performance and stability.

Despite the extensive literature search, we have yet to document any comprehensive paper that is similar to ours (i.e. grounded in firm mathematical models) that analyzed gray project investments by firms. The closest theoretical paper we found is Shleifer & Wolfrenzon (2002), where they also extended Becker (1968) paper and looked at the relationship between investor protection and equity markets to better understand the entrepreneur's decision in going public. In this paper, we use a different set of lens to better understand the firm's decision in allocating resources towards gray investment projects.

In view of the above, this paper proposes a theoretical model that better illustrates the unique nature of corporate crimes and provide useful insights for regulators when it comes to mitigating corporate crime.

3. Model Set-up

This section provides the specific definition of the gray investment project and outlines the basic model that we will use for our analysis in section 4.

3.1 Definition of Gray Investment Projects

We term gray projects as investment projects that firms are committing which they might (or might not) know are illegal investment projects. Furthermore, such an ambiguity is exacerbated due to the complex nature of investment activities and the even more complex regulatory climate. This stands in stark contrast against individual crimes where it is generally known that hurting others, stealing, abusing verbally, etc, are crimes.

The natural implication is that the formal definition of gray investment projects is that the legality is ambiguous. These projects have neither a strict nor clear definition on its legality and in our mathematical models, we define that these projects face a probability of being illegal, given by parameter "g".[2] Based on this definition, it is not unreasonable to propose that all projects that have yet to be classified as illegal is in a transitory state where these projects still have a probability of being illegal subsequently. Some examples of gray investment projects include, cryptocurrency in the technology and finance sector; animal testing in the cosmetics and pharmaceutical sector; poor farming methods (such as slash and burn farming methods, using harmful pesticides) in the agricultural sector; installing defeat devices in cars to fulfil carbon emission quota in the automobile sector; LIBOR manipulation in the finance sector; finite reinsurance in the insurance sector; radium painting in the manufacturing sector; collecting and selling of personal user information in the technology sector; among many others.

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[2] We only assume "g" to be an exogenous probability between 0 and 1, and do not take on any specific distribution. It will be interesting to define specific distributions for parameter "g" in extension paper to identify the effects of different distributions. It will also be interesting for extension papers to generalize the problem to cases with more than one gray investment project, and with different or even random values for "g". Furthermore, it will be extremely insightful for future extensions to consider that firms can choose to allocate their investment budget in decreasing "g". This is applicable to the real-world where firms tend to be actively involved in trying to set the regulatory standards, via lobbying politicians (to ensure that their activities are protected by law), and legal standards (such as hiring smart lawyers to design products that are economically identical but having legally relevant differences).

3.2 Basic Model

This paper begins with a basic model that determines the firm's optimal amount of gray project investment, $\tilde{z}$, if it exists, for a single-firm ecosystem. In subsequent sections, this model is extended to develop propositions that explain and reconcile real-world behavior of corporate crime and punishment.

We begin with a single-firm ecosystem where the firm has a fixed investment budget that will be allocated between two investment projects, a definite legal investment project and a gray investment project denoted as $P_{g=0}$ and $P_{g>0}$ respectively. Furthermore, we propose that there is a perfect alignment of interests between firm managers and shareholders. This implies that there is no agency costs involved.

The budget constraint is as follows:

$$b = y + z,$$

$$y \geq 0,$$

$$z \geq 0,$$

where b is the fixed investment budget, y is the investment in $P_{g=0}$, and z is the investment in $P_{g>0}$. Furthermore, g is defined as the probability of the investment project being illegal.[3]

The expected return on investment in $P_{g=0}$ and $P_{g>0}$ is assumed to be known ex-ante and is denoted by $r_{g=0}$ and $r_{g>0}$ respectively.

We yield the *Expected Revenue* expression as follows:

$$E(Revenue) = y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right).$$

For the gray project investment undertaken by the firm, given that the project turns out to be illegal, there is a likelihood of conviction that we define as the conviction probability

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[3] Note that an absolutely legal project and potentially illegal project is just the trivial case where $g = 0$ and $g > 0$ respectively. The g parameter incorporates the ambiguity in the legality of investment projects.

and the probability function is denoted as $v(z)$ with an exponential distribution (Gordon & Loeb, 2002; Wang, 2017) and is defined as follows:

$$v(z) = \begin{cases} \left(\dfrac{z}{z^*}\right)^{\alpha} & , \quad z < z^* \ and \ \alpha > 1 \\ 1 & , \quad z \geq z^* \end{cases},$$

where z is the gray project investment, z^* is the upper-limit of gray project investments, and α is a firm specific variable that captures the firm's characteristic.[4] z^* is a proxy for the conviction probability density function and the following relationship holds true:

$$For \ all \ z_1^* \geq z_2^* \Rightarrow v_{z_1^*}(z) \leq v_{z_2^*}(z) \ for \ all \ values \ of \ z.$$

The implication is that a firm with a higher z^* will have a conviction likelihood that is less than or equals to another firm with a lower z^*, given that both firms have the same amount of gray project investments, and this holds true at all levels of gray project investments.

> Proposition 1: A firm that has a higher gray project investment will have both a higher conviction probability as well as a higher marginal conviction probability.
>
> (Proof A)

Furthermore, a firm that is convicted for their gray project investments will be subjected to a financial penalty denoted as R. This financial penalty comprises both monetary loss (i.e. fines, legal fees) and non-monetary loss (i.e. reputational loss). We further assume that, unless explicitly stated, all variables are independent of one another.

Next, the expected cost that will be incurred by the firm consists of the capital outlay (i.e., investment budget b, and the expected cost of conviction). Thus, we yield the *Expected Cost* expression as follows:

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[4] Gray project investments exceeding z^* will result in a definite probability of conviction, given that the project turns out to be illegal. For example, if a firm invests \$1,000 in gray projects, the chances of getting caught is likely to be lower than if the firm had invested \$1,000,000 in gray projects. If the z^* for a firm is \$10,000,000, our model assumes that this firm will be convicted if they had invested \$10,000,000 or more in the gray project.

$$E(Cost) = b + [g \cdot v(z) \cdot R].$$

As a result, we have the *Expected Payoff* expression as follows:

$$E(Payoff) = E(Revenue) - E(Cost).$$

Taken together, we define the following optimization problem:

$$\max_{z} \quad E(Profit)$$

$$s.t. \quad b = y + z.$$

Solving the optimization problem, we determine the optimal investments in $P_{g=0}$ and $P_{g>0}$, denoted as $\tilde{y}$ and $\tilde{z}$ respectively, as follows:

$$
\begin{aligned}
\tilde{y} &= & b - \tilde{z} \\
\tilde{z} &= & \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}}
\end{aligned}
$$

(Proof B)

The optimal payoff is thus given as follows:

$$\widetilde{Payoff} = \tilde{y} \cdot r_{g=0} + \tilde{z} \cdot r_{g>0} - [g \cdot v(\tilde{z}) \cdot R]$$

> Proposition 2: A rational firm will never have any investments allocated to gray projects if the condition $r_{g>0} - r_{g=0} < 0$ holds.

Furthermore, our result implies that a rational firm will optimally increase their allocation of investment budget into gray projects when the financial penalty (R) decreases; or probability of the investment project being illegal (g) decreases; or upper-limit of gray project investments (z^*) increases; or excess return of gray investment projects $(r_{g>0} - r_{g=0})$ increases.

Next, we assume that the firm invests the full amount of their investment budget in gray investment projects. For simplicity of analysis, we assume that an investment of the full amount will lead to a definite conviction of the firm. This yields the following conditions:

$$y = 0 \quad \Rightarrow \quad b = z$$
$$b \geq z^* \quad \Rightarrow \quad v(b) = 1'$$

$$E(Payoff) = b \cdot r_{g>0} - g \cdot R.$$

Assuming that the condition $E(Payoff) > 0$ is valid in the real-world. The implication is that all firms will always invest their full investment budget in gray investment projects. This subsequently leads to a conviction. However, in the real-world, we do not see all firms getting convicted, this implies that the prior is false and the converse is true.

> Proposition 3: Assuming that all firms in the real world will have a definite conviction probability if they choose to allocate their full investment budget to gray projects, the following condition will always hold:
> $$b \cdot r_{g>0} - g \cdot R < 0$$
> (Proof C)

The model provides a realistic illustration of the real-world considerations with mathematically tractable results. Next, we provide some insight on the concept of the parameter "g" (i.e. probability that the gray project turns out to be illegal).

In the following sections, the aforementioned model will be extended and some of the results will be used to derive additional solutions. These solutions provide an analytical understanding of a firm's investment behavior in gray investment projects under different settings. Specifically, we will investigate the difference in firm behavior under (i) multi-firm, (ii) multi-period, and (iii) business-friendly regulations settings and the corresponding impact on the firm's optimal amount of gray project investments and, where applicable, the ecosystem's aggregate optimal amount of gray project investments.

4. Model Analyses and Results

4.1 Multi-Firm Setting

In the prior section, our results are derived based on the assumption that the firm operates in a single-firm ecosystem. In this section, we loosen this assumption with a

multi-firm ecosystem. We also present the difference in behavior between a competitive and collusive market.

We begin with the multi-firm ecosystem analysis. To facilitate the analysis, we first assume that the multi-firm ecosystem consists of two firms, firm 1 and firm 2 with the following conviction probability density function respectively:

$$v_1(z_1) = \begin{cases} \left(\dfrac{z_1}{z_1^*}\right)^{\alpha_1} & , \quad z_1 < z_1^* \text{ and } \alpha_1 > 1 \\ 1 & , \quad z_1 \geq z_1^* \end{cases},$$

$$v_2(z_2) = \begin{cases} \left(\dfrac{z_2}{z_2^*}\right)^{\alpha_2} & , \quad z_2 < z_2^* \text{ and } \alpha_2 > 1 \\ 1 & , \quad z_2 \geq z_2^* \end{cases}.$$

Firm 1 and firm 2 face a financial penalty of R_1 and R_2 respectively. To facilitate the analysis, we assume that the investment set (i.e., investment project available) for both firms are the same where each firm allocates their investment budget in $P_{g=0}$ and $P_{g>0}$.[5] In a multi-firm setting, a conviction occurrence for one firm will be dependent on the conviction occurrence of the other firm. Specifically, a contagion effect could take hold where a firm's conviction can trigger the regulator to come down more harshly on the other errant firms. In addition, the conviction of one firm provides a learning opportunity for the regulator who now possesses a more complete information set and can better utilize this information set to clamp down on other errant firms. Our analysis will be based on the contagion effect as this is likely to be more prevalent in the real-world. To illustrate this concept of dependency between both firms, we define the following contagion probability matrix:[6]

$$\begin{pmatrix} 1 & \tau_{1,2} \\ \tau_{2,1} & 1 \end{pmatrix} \quad , \quad \tau_{i,j} > 0 \text{ and } i = 1,2 \text{ and } j = 1,2,$$

where $\tau_{i,j}$ is the contagion probability of firm j being convicted conditioned on the conviction of firm i. With the assumption of independence between the conviction

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[5] Without this assumption, the investment behavior between both firms will be confounded by their investment set and not exactly by the multi-firm setting (i.e. our interest of analysis).
[6] $\tau_{i,j} < 0$ implies the complacency effect while $\tau_{i,j} = 0$ implies independence in the conviction probability of both firms.

probability between firm 1 and firm 2, we yield the respective combined conviction probability density function for firm 1 and firm 2:[7]

$$
v_1(z_1, z_2) = \begin{cases} \left(\frac{z_1}{z_1^*}\right)^{\alpha_1} + \left(\frac{z_2}{z_2^*}\right)^{\alpha_2} \cdot \tau_{2,1} - \left(\frac{z_1}{z_1^*}\right)^{\alpha_1}\left(\frac{z_2}{z_2^*}\right)^{\alpha_2} \cdot \tau_{2,1} &, \quad z_1 < z_1^* \ and \ \alpha_1 > 1 \\ 1 &, \quad z_1 \geq z_1^* \end{cases},
$$

$$
v_2(z_2, z_1) = \begin{cases} \left(\frac{z_1}{z_1^*}\right)^{\alpha_1} \cdot \tau_{1,2} + \left(\frac{z_2}{z_2^*}\right)^{\alpha_2} - \left(\frac{z_1}{z_1^*}\right)^{\alpha_1}\left(\frac{z_2}{z_2^*}\right)^{\alpha_2} \cdot \tau_{1,2} &, \quad z_2 < z_2^* \ and \ \alpha_2 > 1 \\ 1 &, \quad z_2 \geq z_2^* \end{cases}.
$$

In a competitive market, each firm will maximize their individual expected payoff which gives rise to the following *Expected Profit* expression for firm 1 and firm 2 respectively:

$$
E(Payoff)_1 = y_1 \cdot r_{g=0} + z_1 \cdot r_{g>0} - R_1 \cdot g \cdot v_1(z_1, z_2),
$$

$$
E(Payoff)_2 = y_2 \cdot r_{g=0} + z_2 \cdot r_{g>0} - R_2 \cdot g \cdot v_2(z_2, z_1).
$$

In a similar manner as the single-firm ecosystem, we solve the optimization under constraint and determine the optimal investments in gray projects for firm 1 and firm 2 respectively, as follows:

$$
\tilde{z}_1^{competition} = \left[\frac{(z_1^*)^{\alpha_1} \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha_1 \cdot g \cdot R_1 \cdot \left(1 - v_2(z_2) \cdot \tau_{2,1}\right)} \right]^{\frac{1}{\alpha_1 - 1}},
$$

$$
\tilde{z}_2^{competition} = \left[\frac{(z_2^*)^{\alpha_2} \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha_2 \cdot g \cdot R_2 \cdot \left(1 - v_1(z_1) \cdot \tau_{1,2}\right)} \right]^{\frac{1}{\alpha_2 - 1}}.
$$

> Proposition 4: In a competitive multi-firm market under the contagion effect, relative to a single-firm ecosystem (i.e., $z_1^* = z_2^* = z^*$), the market's aggregate investments in gray projects will be higher.
>
> (Proof D)

---

[7] The combined conviction probability for firm i is given by (conviction probability of firm i) + (conviction probability of firm j * contagion probability from firm j to firm i) − (joint probability of both events occurring simultaneously).

In a market where firms collude, firms will seek to maximize the industry's expected payoff which gives rise to the following *Expected Profit* expression for a two-firm market:

$$E(P)_m = (y_1 + y_2) \cdot r_{g=0} + (z_1 + z_2) \cdot r_{g>0} - g \cdot [R_1 \cdot v_1(z_1|z_2) + R_2 \cdot v_2(z_2|z_1)].$$

Solving the optimization under constraint yields the optimal investments in gray projects for firm 1 and firm 2 respectively, as follows:

$$\tilde{z}_1^{collusion} = \left[\frac{(z_1^*)^{\alpha_1} \cdot (r_{g>0} - r_{g=0})}{\alpha_1 \cdot g \cdot [R_1 \cdot (1 - v_2(z_2) \cdot \tau_{2,1}) + R_2 \cdot \tau_{1,2} \cdot (1 - v_2(z_2))]} \right]^{\frac{1}{\alpha_1 - 1}},$$

$$\tilde{z}_2^{collusion} = \left[\frac{(z_2^*)^{\alpha_2} \cdot (r_{g>0} - r_{g=0})}{\alpha_2 \cdot g \cdot [R_2 \cdot (1 - v_1(z_1) \cdot \tau_{1,2}) + R_1 \cdot \tau_{2,1} \cdot (1 - v_1(z_1))]} \right]^{\frac{1}{\alpha_2 - 1}}.$$

> Proposition 5: In a collusive multi-firm market under the contagion effect, the self-policing effect takes hold and the market's aggregate investments in gray projects will be lesser than that of a competitive multi-firm market, subjected to similar conditions.
>
> (Proof E)

Within a multi-firm market where a firm's conviction will lead to an increase in the combined conviction probability of all other firms within the ecosystem, our results provide support for the presence of some form of collusion agreements. This is because the aggregate gray project investments in a collusive market is lower than that of a competitive market. We term this as a self-policing effect, where the colluding firms will monitor the gray project investments of other firms. Assuming that both scenarios are subjected to similar regulatory scrutiny, we see that firms in the collusive market will have a preference of self-regulation. This is because they are implicitly required to internalize the costs of their gray project investments because they are contemporaneously impacted by the gray project investments of other firms. Furthermore, for firm i, $\tau_{i,j}$ can be viewed as the firm's export contagion probability to firm j. In a similar fashion, $\tau_{j,i}$ can be viewed as the firm's import contagion probability from firm j.

Proposition 6: In both a competitive and collusive multi-firm market, a firm's optimal amount of gray project investment is increasing in the firm's import contagion probability.

Proposition 7: In a competitive multi-firm market, all firms ignore their export contagion probability, while in a collusive multi-firm market, each firm's optimal amount of gray project investment is decreasing in the firm's export contagion probability.

Our results here hold important implication for law regulators. The notion of a "ratting out system" is not new, where criminals *turn state's evidence* by admitting guilt and subsequently testify for the state against their accomplice, often in exchange for leniency in sentencing or even immunity from prosecution. Similarly, regulators might provide convicted firms with an opportunity to turn against bigger firms in a bid to "catch the bigger fish". In such an ecosystem, we can see that the regulators increase the contagion probability by providing strong incentives for convicted firms to implicate other erring firms. However, our results suggest that keeping all else equal, a higher $\tau_{j,i}$ will increase the firm i's optimal amount of gray project investment in both a competitive and collusive market. In a competitive market, each firm is adversely affected when another firm increases their gray project investment. Thus, to ensure that they are not losing out, they will increase their own gray project investment. This results in a vicious cycle where all firms continuously increase their gray project investment. Such an effect is made worse when $\tau_{j,i}$ is increased via the "ratting out" system. For collusive market, the same effect is present but is mitigated by firm i's $\tau_{i,j}$, as each firm internalizes the costs of their gray project investments. Thus, it is important for regulators to understand that having a "ratting out system" can indeed increase the aggregate gray project investment in the economy. This is especially so in a competitive market, and much care and consideration must be given when setting such systems.

4.2 Multi-Period Setting

This section investigates the intertemporal gray project investment behavior of a firm. In order to incorporate the notion of time into the model, we extend our basic model with a time function, φ.[8] The model underlying φ is that as time proceeds into a later time period, holding all else constant, it will result in a higher likelihood of conviction. The notion is that as time passes, more information regarding the gray project investment is released and this increases their conviction likelihood. For the simplicity of analysis, we first assume a 2-time period model with the following conviction probability function:

$$v(z_t) = \begin{cases} \left(\frac{z_t}{z^*}\right)^{\alpha\varphi}, & z_t < z^* \ and \ \alpha > 1 \ and \ \varphi = e^{-(t-1)\cdot\left(1-\frac{z_{t-1}}{z^*}\right)}, \\ 1, & z_t \geq z^* \end{cases}$$

where z_t is investments in gray projects at time $t = 1, 2$.

We seek to maximize the expected payoff at each time period and it follows that:

$$v(z_1) = \left(\frac{z_1}{z^*}\right)^{\alpha}, where \ z_1 < z^*,$$

$$\tilde{z}_1 = \left(\frac{(z^*)^{\alpha}}{\alpha} \cdot \frac{\left(r_{g>0} - r_{g=0}\right)}{g \cdot R}\right)^{\frac{1}{\alpha-1}}.$$

And that:

$$v(z_2) = \left(\frac{z_2}{z^*}\right)^{\omega}, where \ z_2 < z^* \ and \ \omega = \alpha e^{-\left(1-\frac{\tilde{z}_1}{z^*}\right)},$$

$$\tilde{z}_2 = \left(\frac{(z^*)^{\omega}}{\omega} \cdot \frac{\left(r_{g>0} - r_{g=0}\right)}{g \cdot R}\right)^{\frac{1}{\omega-1}}.$$

Making a simple comparison of the local optimal amount of gray project investment between time *1* and *2*, we can easily see that the expression is similar where:

$$\tilde{z}_1 = f(\alpha),$$

---

[8] We define our time function in a similar manner to our conviction probability function, as an exponential function. Our time function implicitly incorporates the notion that the conviction probability increases when more information had been collected.

$$\tilde{z}_2 = f(\omega)$$
$$= f[g(\alpha)]$$
$$= f\left[\alpha e^{-\left(1-\frac{\tilde{z}_1}{z^*}\right)}\right]$$
$$= f[\alpha \cdot (Scaling\ Factor)].$$

> Proposition 8: A firm that chooses a fixed investment strategy (i.e. fixed amount invested) across time will experience an increase in conviction probability over time.
>
> (Proof F)

Our result here shows that a firm that has fixed their investments in gray projects will experience an increase in conviction probability as time passes. This is a reasonable result as across time, the firm might be more prone to leaving crucial evidence on their gray project investments that can convict them. It is also a norm that regulators will collect information on the firm's operating activities and as time passes, more information can be collected. This makes it easier for regulators to convict the firms for their gray project investments, given that their projects turn out to be illegal.

> Proposition 9: A firm that meets the following condition will continuously meet the condition across all later time periods and will choose to increase their gray project investments across all future time periods:
>
> $$\frac{1}{\log_e\left(\frac{z^*}{\tilde{z}_t}\right)} > \alpha$$
>
> (Proof G)

Our prior result documents that a firm's conviction probability increases across time even if they maintain a fixed investment contract for each time period. We further found that in spite of such an increase in the firm's conviction probability, the firm's optimal amount of gray project investment will increase if the abovementioned condition is met. Furthermore, this increment will persist in all future time periods. The condition will only be unmet if an external shock comes into the system (i.e. regulators spending on regulation and leads to an exogenous decrease in z^*).

Proposition 10: A firm will optimally choose to reduce their gray project investments across time if the following condition holds.

$$\frac{1}{\log_e\left(\frac{z^*}{\tilde{z}_t}\right)} < \alpha$$

However, unlike Proposition 9, fulfilling the condition does not guarantee that the condition will continue to be met in all future time periods.

(Proof H)

Taken together, our results are of great significance for regulators. Our results imply that if a firm is left alone for a sufficiently long period of time with no external shock to the system, the firm will eventually meet the condition in Proposition 9 (i.e. no shock to the system). This will result in the firm to increase her optimal amount of gray project investment for all later periods. Our results make the case for government intervention in the market, to have the government shock the system by decreasing z^* and to discourage firms from increasing their gray project investments across time.

Proposition 11: The condition given in Proposition 10 will always hold if the following holds:

$$\frac{z^*}{\tilde{z}_t} > e^1$$

(Proof I)

Our result provides regulators with a potential proxy to test if the firm will decrease their optimal amount of gray project investments in the subsequent time period.[9] We show that if the percentage of the firm's gray project investment to the upper-limit of gray project investments is less than _36.787%_, this is a sufficient condition to show that the firm will continue to reduce their optimal amount of gray project investment in the subsequent period. However, regulators should be aware that this condition needs to be checked at every time period. This is because our prior results have shown that if firms are left on

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[9] The boundary condition is similar to the results derived in the cybersecurity investments literature, which explores similar exponential power class probability function (Gordon & Loeb, 2002; Wang, 2017).

their own for a sufficiently long enough time period, the condition will eventually be unmet and firms will then increase their optimal amount of gray project investments for all later time periods.

Another key implication from our result is that factors such as returns on investments, imposed penalty and the probability that the investment project turns out to be illegal are not considered by firms when they make decision on whether to increase or decrease the firm's optimal amount of gray project investment across time. The implication is that the firm only considers these three factors (i.e. returns on investments, imposed penalty and the probability that the investment project turns out to be illegal) when making the initial investment in gray projects. Subsequently, as these three factors are time-invariant, the firm will not take these factors into account when deciding to adjust the investment in gray projects at later time periods. However, it is important to note that the firm will still consider these factors when making the initial investment in gray projects (i.e. at $t = 0$).

Our paper provides the foundation for multiple extension papers that can be done in future research. It is interesting to consider an overall (i.e. terminal) payoff maximization across all time periods in extension papers. Furthermore, it will be insightful to combine the multi-period and multi-firm model into a single setting, and game theory can be incorporated as well to yield more interesting results.

4.3 Business-friendly regulations

In the prior sections, we assume that the returns from legal investment projects and gray investment projects remain constant. This section illustrates the behavior of firm's investments in gray projects when regulators seek to nurture a more business-friendly ecosystem. This in turn impacts the return from legal investment projects. We propose that business-friendly regulations increases the returns for legal investment projects, as opposed to gray investment projects. This is because business-friendly regulations make it easier to conduct legal investment projects; whereas the same cannot be said for gray investment projects.

We propose that the excess return of gray investment project against legal investment project is given as follows:

$$Excess\ return\ of\ gray\ investment\ project = r_{gray} - \psi \cdot r_{legal},$$

$$where\ \psi\ is\ investments\ in\ business\text{-}friendly\ regulations\ by\ regulators.$$

> Proposition 12: Excess return of gray investment project decreases as regulators invest in business-friendly regulations.

Proposition 12 implies that as regulators invest in making the ecosystem more friendly for businesses, this will reduce the excess returns of gray project investments. For example, when the regulators have a highly transparent process for the issuance of construction permits, this streamlined process can help to reduce the costs for construction companies. Therefore, the cost of constructing a building (i.e. a legal investment project) is now lower. This helps to increase the return for the legal investment project. As a highly transparent process for the issuance of construction permits does not impact the costs for gray investment projects, the result is that business-friendly investments by regulators has effectively reduced the excess return of gray investment project.

Coupling this result into our optimization problem in section 3, we yield the following solution:

$$
\begin{aligned}
\tilde{y} &= b - \tilde{z} \\
\tilde{z} &= \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - \psi r_{g=0}\right)}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}}
\end{aligned}
$$

> Proposition 13: The optimal gray project investment decreases as the level of regulator's investments in business-friendly regulations increases:
> $$\frac{\partial \tilde{z}}{\partial \psi} < 0$$
> (Proof J)

Our results here imply that as the level of investments made by regulators to nurture a more business-friendly ecosystem for companies, the optimal gray project investment decreases. This arises from the notion that as the excess return from gray project investment decreases, firms find that the marginal benefit from investing an additional dollar in gray project investment is now lower.

Our results here hold significant importance for regulators. Regulators can help to reduce the cost of legal investment project by investing more resources into creating a more business-friendly environment. This helps to increase the returns from legal investment project and reduces the excess returns from gray projects. Taken together, the optimal level of gray project investments from companies will now be lower in response to the investments in business-friendly regulations from regulators. Our results here provide a strong case for regulators to have more business-friendly regulations, as this can help to bring down the aggregate level of gray project investments in the ecosystem.

5. Empirical Analyses

This section conducts data analysis to show that the propositions within this paper ties in with empirical data. Due to the nature of gray project investments, companies do not usually publicly announce the level of gray project investments undertaken by the firm. Therefore, it is difficult to conduct holistic analyses concerning gray project investments. Due to limited data available, we are only able to show specific propositions to hold true. Specifically, we test the implication from Proposition 13 where gray project investments ($\tilde{z}$) decrease in regulator's investment in business-friendly regulations (ψ) with a country panel dataset.

We propose that a proxy for ψ can be identified from how easy it is to conduct business within a country. This is because as investments in business-friendly regulations increase, the consequence is an increase in the ease of doing business within the country. However, it is difficult to ascertain the level of $\tilde{z}$ within the country. We propose that a reasonable proxy for the level of $\tilde{z}$ within the country will be the level of corruption within the country. This is fundamentally because when firms engage in higher levels of $\tilde{z}$, they seek to reduce

their conviction probability by means of lobbying or at times, bribing of politicians. On the other hand, if firms are not engaging in gray project investments (i.e. their investments are all legal), then the need to bribe politicians diminish significantly. Therefore, we propose that the level of corruption within a country can be a reasonable proxy for $\tilde{z}$.

Data Description: Our data comes from two sources. The measures for ease of doing business comes from the "Ease of Doing Business Index Database" from the World Bank. The database tracks the ease of doing businesses across 190 countries from 2004 to 2019. As several different factors were used in constructing the ease of doing business index, we extracted the nine most relevant factors and divided these factors into 3 main groups. The first group measures how easy it is to set up a company in the country, and we proxy that with *ConstructionPermit*, *PropertyRegistration*, and *StartBusiness*; the second group measures how readily financing is available for companies, and we proxy that with *ProtectMinorityInvestors*, *ResolvingInsolvency*, and *AccessToCredit*; and the third group measures how easy it is for companies to conduct their day to day operations, and we proxy that with *CrossBorderTrade*, *AccessToElectricity*, and *EaseOfPayingTaxes*. The second database we used is from Transparency International which captures the "Corruption Perceptions Index" (*CPIscore*) for 177 countries from 2012 to 2018. We use the *CPIscore* as our proxy for $\tilde{z}$.

Table 1 shows the summary statistics of the data. Detailed variable descriptions are in Table A1. Panel A summarizes the data of our main sample on the country × year level, with a total of 1,210 observations from 2012 to 2018. Panel B summarizes the unique number of observations in our dataset.

CPIscore is the Corruption Perception Index score for the country in the year of observation, as documented by Transparency International. The mean is 42.349, which means that the average score in our sample is below the midpoint score of 50. For brevity, the remaining variables are our key independent variables of interest, and these variables are extracted from the "Ease of Doing Business Index Database" from the World Bank.

[Place Table 1 about here]

We apply the following linear model with both country- and year-fixed effects to mitigate concerns about omitted variables and control for both time-variant and time-invariant factors:

$$CPIscore_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta(Independent\ variable\ of\ interest)_{i,t} + \varepsilon_{it} \quad -(1)$$

where $\alpha_0,\ \alpha_i,\ and\ \alpha_t$ represent the constant, country i fixed-effect and year t fixed-effect, respectively. The normally distributed error term is denoted by ε_{it}. The dependent variable is the *CPIscore*, which proxies for the level of $\tilde{z}$ in our dataset. Our independent variable of interest are the nine different variables that measure the ease of doing business within a country. We are primarily interested in estimating the parameter β as it captures the influence of the ease of doing business on the country's *CPIscore*. We also cluster our standard errors by country.

We first focus on the group of measures that look at the ease of setting up a company within the country: *ConstructionPermit*, *PropertyRegistration*, and *StartBusiness*, results are reported in Table 2. In column (1), we do not control for fixed-effects and the estimated β coefficient for *ConstructionPermit* is 0.0579 and is significant at the 1% level. This means that as the ease of obtaining a construction permit increases in score by 1 point, this leads to an increase in *CPIscore* of 0.0579 point, and this corresponds with a reduction in corruption level of the country. In columns (4) and (7), we repeat the similar analyses with *PropertyRegistraion* and *StartBusiness* as our key independent variable of interest, and we document that the estimated coefficient is 0.0840 and 0.0523, with a significance of 1% and 5%, respectively. Furthermore, to account for time-variant effects, we control for year-fixed effects in columns (2), (5), and (8) and continue to document robust results. Finally, we also control for country-fixed effects, to account for time-invariant effects, in columns (3), (6), and (9) and results continue to remain robust. Taken together, our results show that an improvement in the ease of setting up a company in a country is positively associated with a reduction in corruption level of the country.

[Place Table 2 about here]

Next, we focus on the group of measures that look at the accessibility of getting financing within the country: *ProtectMinorityInvestors*, *ResolvingInsolvency*, and *AccessToCredit*,

results are reported in Table 3. In column (1), we do not control for fixed-effects and the estimated β coefficient for *ProtectMinorityInvestors* is 0.0834 and is significant at the 1% level. This means that as the protection of minority investors increases in score by 1 point, this leads to an increase in *CPIscore* of 0.0834 point, and this corresponds with a reduction in corruption level of the country. In columns (4) and (7), we repeat the similar analyses with *ResolvingInsolvency* and *AccessToCredit* as our key independent variable of interest, and we document that the estimated coefficient is 0.0725 and 0.0308, with a significance of 1% and 5%, respectively. Furthermore, to account for time-variant effects, we control for year-fixed effects in columns (2), (5), and (8) and continue to document robust results. Finally, we also control for country-fixed effects, to account for time-invariant effects, in columns (3), (6), and (9) and results continue to remain robust. Taken together, our results show that an improvement in the accessibility of getting credit in a country is positively associated with a reduction in corruption level of the country.

[Place Table 3 about here]

Third, we focus on the group of measures that look at support for businesses to conduct day to day operations within the country: *CrossBorderTrade*, *AccessToElectricity*, and *EaseOfPayingTaxes*, results are reported in Table 4. In column (1), we do not control for fixed-effects and the estimated β coefficient for *CrossBorderTrade* is 0.0476 and is significant at the 1% level. This means that as the ease of conducting cross border trades increases in score by 1 point, this leads to an increase in *CPIscore* of 0.0476 point, and this corresponds with a reduction in corruption level of the country. In columns (4) and (7), we repeat the similar analyses with *AccessToElectricity* and *EaseOfPayingTaxes* as our key independent variable of interest, and we document that the estimated coefficient is 0.0578 and 0.0668, both with a significance of 1%. Furthermore, to account for time-variant effects, we control for year-fixed effects in columns (2), (5), and (8) and continue to document robust results. Finally, we also control for country-fixed effects, to account for time-invariant effects, in columns (3), (6), and (9) and results continue to remain robust. Taken together, our results show that an improvement in the ability for firms to conduct standard day to day operations in a country is positively associated with a reduction in corruption level of the country.

[Place Table 4 about here]

Furthermore, we conduct two sets of robustness tests. The first set of robustness test, we further control for the income level of the country in our regressions, to account for potential explanatory power arising from the income level of the country on the corruption level of the country. We repeat the analyses in Tables 2, 3, and 4 with the control for income level and results are documented in Tables A2, A3, and A4, respectively, and we continue to document robust results. In the second set of robustness test, we replace country fixed effects by region fixed-effects. We also cluster our standard errors by region, this is to account for specific time-invariant fixed effects across regions that are not captured by the country fixed-effects. We repeat the analyses in Tables 2, 3, and 4 with this robustness test and results are documented in Tables A5, A6 and A7, respectively, and our results continue to remain robust to these checks.

Taken together, our results show that when the ease of doing business in a country improves (as captured by "ease of setting up a company", "getting access to financing", and "convenience in day to day operations"), this results in a reduction in corruption level in the country. Given that our various measures for ease of doing business is a good proxy for investments in business-friendly regulations made by regulators, and that *CPIscore* is a good proxy for $\tilde{z}$, our results lend credence to the various propositions derived from our model, as well as the validity of the model.

6. Conclusion

In sum, our paper provides a basic model that analyzes the decision making process of firms when it comes to gray project investments. Our model sheds light on unethical decision making by firms that maximizes shareholder value at the expense of social value. We then provided different settings to gain a better understanding of firm's decision making behavior in the real-world. Our paper is also the first paper that provides a robust mathematical model that analyzes firm's decision making behavior in terms of gray investment project. Our paper makes a strong assumption that firm managers' incentives are perfectly aligned with that of the firm, an assumption that might not necessarily hold in the real-world. Thus, more research could be done on gaining a better understanding

of how an agency problem between firm managers and the shareholders can exacerbate these issues. Furthermore, given that more firms are being sued for compromising on social value, more research could be done to mitigate gray project investments by firms in the economy and maximize societal value instead. In response to this, we conduct more research concerning these issues in chapters 2 and 3.

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Table 1
Summary Statistics

Panel A: Country x Year

Variables	Observations	Mean	S.D.	Min	Max
CPIscore	1,208	43.249	19.480	8	92
ConstructionPermit	1,210	63.104	16.399	0	92
PropertyRegistration	1,210	63.424	17.112	0	100
StartBusiness	1,210	78.796	15.063	15	100
ProtectMinorityInvestors	1,210	51.777	15.135	0	97
ResolvingInsolvency	1,210	42.055	24.930	0	98
AccessToCredit	1,210	49.837	23.258	0	100
CrossBorderTrade	1,210	67.443	22.305	0	100
AccessToElectricity	1,210	67.094	18.970	0	100
EaseOfPayingTaxes	1,210	68.221	17.975	0	100

Panel B: Unique no. of observations

Variables	Observations
Unique no. of countries	177
Unique no. of years	7
Unique no. of regions	6
Unique no. of income groups	4

Notes: This table describes the summary statistics of our sample. Panel A provides the summary statistics at the country x year level for our panel database. Panel B describes that the data are restricted to 177 unique countries of 4 different income groups across 6 regions between 2012 and 2018. See Table A1 for detailed variable definitions.

Table 2
CPI Score and Setting Up A Company Measures

Dependent Variable	1 CPIscore	2 CPIscore	3 CPIscore	4 CPIscore	5 CPIscore	6 CPIscore	7 CPIscore	8 CPIscore	9 CPIscore
ConstructionPermit	0.0579***	0.0588***	0.0449***						
	(0.0130)	(0.0138)	(0.0138)						
PropertyRegistration				0.0840***	0.0970***	0.0638*			
				(0.0288)	(0.0323)	(0.0336)			
StartBusiness							0.0523**	0.0631***	0.0435*
							(0.0205)	(0.0230)	(0.0236)
Constant	39.67***	39.83***	40.83***	37.99***	37.17***	39.44***	39.18***	38.70***	40.32***
	(1.611)	(1.593)	(0.807)	(2.163)	(2.513)	(2.231)	(2.001)	(1.996)	(1.761)
Observations	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.023			0.017			0.017
Chi-squared	19.74	34.72		8.509	30.72		6.523	32.41	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ConstructionPermit*, columns (4)-(6) report results for the *PropertyRegistration*, and columns (7)-(9) report results for the *StartBusiness*. These three are measures for the ease of setting up a company, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3
CPI Score and Accessing Financing Measures

Dependent Variable	1 CPIscore	2 CPIscore	3 CPIscore	4 CPIscore	5 CPIscore	6 CPIscore	7 CPIscore	8 CPIscore	9 CPIscore
ProtectMinorityInvestors	0.0834***	0.0879***	0.0630**						
	(0.0281)	(0.0290)	(0.0300)						
ResolvingInsolvency				0.0725***	0.0858***	0.0447**			
				(0.0178)	(0.0193)	(0.0191)			
AccessToCredit							0.0308**	0.0414***	0.0297*
							(0.0144)	(0.0151)	(0.0159)
Constant	38.99***	39.00***	40.40***	40.25***	40.15***	41.86***	41.77***	41.20***	41.98***
	(1.990)	(1.977)	(1.530)	(1.452)	(1.429)	(0.746)	(1.578)	(1.575)	(0.880)
Observations	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.021			0.020			0.015
Chi-squared	8.815	32.60		16.54	38.60		4.582	32.61	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ProtectMinorityInvestors*, columns (4)-(6) report results for the *ResolvingInsolvency*, and columns (7)-(9) report results for the *AccessToCredit*. These three are measures for the ease of getting financing, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 4
CPI Score and Day to Day Operations Measures

	1	2	3	4	5	6	7	8	9
Dependent Variable	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore
CrossBorderTrade	0.0476***	0.0498***	0.0348**						
	(0.0136)	(0.0137)	(0.0141)						
AccessToElectricity				0.0578***	0.0606***	0.0401*			
				(0.0200)	(0.0208)	(0.0211)			
EaseOfPayingTaxes							0.0668***	0.0688***	0.0349*
							(0.0197)	(0.0206)	(0.0209)
Constant	40.11***	40.22***	41.34***	39.44***	39.32***	40.86***	38.77***	38.86***	41.25***
	(1.629)	(1.590)	(0.928)	(1.811)	(1.947)	(1.477)	(1.672)	(1.674)	(1.382)
Observations	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.027			0.020			0.013
Chi-squared	12.23	32.77		8.360	29.84		11.51	37.38	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *CrossBorderTrade*, columns (4)-(6) report results for the *AccessToElectricity*, and columns (7)-(9) report results for the *EaseOfPayingTaxes*. These three are measures for the ease of conducting standard day to day operations, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix

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Table AI

Variable Definitions and Constructions

</div>

Variable	Description
CPIscore	*Corruption Perception Index (CPI) Score*, extracted from Transparency International. The score is computed by accounting for various aspects of corruption, and the score ranges from 0 (highly corrupt) to 100 (very clean).
ConstructionPermit	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *ConstructionPermit* is a proxy for the ease of setting up a business, and is a score that ranges from 0 to 100, where the higher the score implies a greater ease for businesses in dealing with construction permits.
PropertyRegistration	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *PropertyRegistration* is a proxy for the ease of setting up a business, and is a score that ranges from 0 to 100, where the higher the score implies a greater ease for businesses in registering for a property.
StartBusiness	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *StartBusiness* is a proxy for the ease of setting up a business, and is a score that ranges from 0 to 100, where the higher the score implies a greater ease for businesses in starting a business.
ProtectMinorityInvestors	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *ProtectMinorityInvestors* is a proxy for the ease of access to financing, and is a score that ranges from 0 to 100, where the higher the score implies a greater protection of interests of minority investors.
ResolvingInsolvency	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *ResolvingInsolvency* is a proxy for the ease of access to financing, and is a score that ranges from 0 to 100, where the higher the score implies a set of more matured protocols in resolving insolvencies of companies.
AccessToCredit	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *AccessToCredit* is a proxy for the ease of access to financing, and is a score that ranges from 0 to 100, where the higher the score implies businesses have access to credit more readily.
CrossBorderTrade	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *CrossBorderTrade* is a proxy for the ease of conducting day to day operations, and is a score that ranges from 0 to 100, where the higher the score implies a greater ease in conducting cross border trades.
AccessToElectricity	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *AccessToElectricity* is a proxy for the ease of conducting day to day operations, and is a score that ranges from 0 to 100, where the higher the score implies that electricity is more readily available.
EaseOfPayingTaxes	The data is extracted from the Ease of Doing Business Database compiled by the World Bank. *EaseOfPayingTaxes* is a proxy for the ease of conducting day to day operations, and is a score that ranges from 0 to 100, where the higher the score implies a greater ease in paying taxes for businesses.
Regions	Our dataset consists of countries divided into 6 regions: Americas, Asia Pacific, Europe & Central Asia, Middle East & North Africa, Sub-Saharan Africa, and Western Europe/European Union
Income groups	Our data consists of countries divided into 4 income groups: High, Upper Middle, Lower Middle, and Low.

CPI Score and Setting Up A Company Measures (Robustness Test: Income level)

Dependent Variable	1 CPIscore	2 CPIscore	3 CPIscore	4 CPIscore	5 CPIscore	6 CPIscore	7 CPIscore	8 CPIscore	9 CPIscore
ConstructionPermit	0.0733*** (0.0236)	0.0791*** (0.0263)	0.0441** (0.0210)						
PropertyRegistration				0.134*** (0.0384)	0.151*** (0.0401)	0.0879** (0.0407)			
StartBusiness							0.165*** (0.0238)	0.190*** (0.0291)	0.154*** (0.0249)
Constant	47.36*** (3.140)	47.54*** (3.203)	42.77*** (1.623)	42.78*** (3.714)	42.04*** (4.063)	39.70*** (2.937)	37.54*** (3.392)	36.27*** (3.482)	33.07*** (2.272)
Observations	738	738	738	738	738	738	738	738	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
IncomeFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.030			0.033			0.086
Chi-squared	22.09	37.74		25.23	44.56		80.49	103.5	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ConstructionPermit*, columns (4)-(6) report results for the *PropertyRegistration*, and columns (7)-(9) report results for the *StartBusiness*. These three are measures for the ease of setting up a company, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A3
CPI Score and Accessing Financing Measures (Robustness Test: Income level)

	1	2	3	4	5	6	7	8	9
Dependent Variable	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore
ProtectMinorityInvestors	0.149***	0.160***	0.109***						
	(0.0390)	(0.0389)	(0.0414)						
ResolvingInsolvency				0.0792***	0.0954***	0.0559**			
				(0.0235)	(0.0249)	(0.0247)			
AccessToCredit							0.0296	0.0407**	0.0301
							(0.0181)	(0.0202)	(0.0210)
Constant	43.66***	43.88***	40.24***	46.94***	47.22***	42.70***	49.78***	49.24***	43.51***
	(3.465)	(3.522)	(2.286)	(2.898)	(3.012)	(1.663)	(3.024)	(3.207)	(1.739)
Observations	738	738	738	738	738	738	738	738	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
IncomeFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.058			0.040			0.026
Chi-squared	26.98	43.27		23.99	42.77		13.19	29.88	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ProtectMinorityInvestors*, columns (4)-(6) report results for the *ResolvingInsolvency*, and columns (7)-(9) report results for the *AccessToCredit*. These three are measures for the ease of getting financing, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A4
CPI Score and Day to Day Operations Measures (Robustness Test: Income level)

	1	2	3	4	5	6	7	8	9
Dependent Variable	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore
CrossBorderTrade	0.0517**	0.0557***	0.0335						
	(0.0211)	(0.0210)	(0.0216)						
AccessToElectricity				0.0962***	0.0976***	0.0607*			
				(0.0318)	(0.0321)	(0.0348)			
EaseOfPayingTaxes							0.0833***	0.0877***	0.0520**
							(0.0266)	(0.0282)	(0.0260)
Constant	48.08***	48.51***	43.21***	44.65***	44.89***	41.23***	45.83***	46.06***	41.71***
	(3.237)	(3.291)	(1.846)	(3.640)	(3.752)	(2.707)	(3.479)	(3.551)	(2.067)
Observations	738	738	738	738	738	738	738	738	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
IncomeFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY
R-squared			0.034			0.038			0.031
Chi-squared	19.34	33.70		22.22	39.23		23.76	40.21	

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *CrossBorderTrade*, columns (4)-(6) report results for the *AccessToElectricity*, and columns (7)-(9) report results for the *EaseOfPayingTaxes*. These three are measures for the ease of conducting standard day to day operations, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A5

CPI Score and Setting Up A Company Measures (Robustness Test: Region)

Dependent Variable	1 CPIscore	2 CPIscore	3 CPIscore	4 CPIscore	5 CPIscore	6 CPIscore	7 CPIscore	8 CPIscore	9 CPIscore
ConstructionPermit	0.0560***	0.0572***	0.0700**						
	(0.0115)	(0.0122)	(0.0356)						
PropertyRegistration				0.0776***	0.0899***	0.140***			
				(0.0246)	(0.0172)	(0.0299)			
StartBusiness							0.0498	0.0602*	0.185***
							(0.0370)	(0.0318)	(0.0268)
Constant	40.74***	40.88***	44.30***	39.67***	38.93***	40.02***	40.48***	40.03***	33.80***
	(0.747)	(0.816)	(3.132)	(1.489)	(1.077)	(2.509)	(2.881)	(2.612)	(3.719)
Observations	1,180	1,180	738	1,180	1,180	738	1,180	1,180	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
RegionFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IncomeFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ConstructionPermit*, columns (4)-(6) report results for the *PropertyRegistration*, and columns (7)-(9) report results for the *StartBusiness*. These three are measures for the ease of setting up a company, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) only include region fixed-effects, columns (2), (5), and (8) include both year- and region-fixed effects, and columns (3), (6) and (9) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A6
CPI Score and Accessing Financing Measures (Robustness Test: Region)

	1	2	3	4	5	6	7	8	9
Dependent Variable	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore	CPIscore
ProtectMinorityInvestors	0.0797***	0.0840***	0.147***						
	(0.0206)	(0.0233)	(0.0400)						
ResolvingInsolvency				0.0593***	0.0687***	0.0827***			
				(0.0147)	(0.0166)	(0.0192)			
AccessToCredit							0.0287	0.0391*	0.0385
							(0.0251)	(0.0219)	(0.0302)
Constant	40.43***	40.47***	41.69***	42.01***	42.03***	44.95***	42.80***	42.19***	45.70***
	(1.018)	(1.031)	(3.017)	(0.584)	(0.592)	(3.064)	(1.375)	(1.201)	(3.272)
Observations	1,180	1,180	738	1,180	1,180	738	1,180	1,180	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
RegionFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IncomeFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *ProtectMinorityInvestors*, columns (4)-(6) report results for the *ResolvingInsolvency*, and columns (7)-(9) report results for the *AccessToCredit*. These three are measures for the ease of getting financing, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) only include region fixed-effects, columns (2), (5), and (8) include both year- and region-fixed effects, and columns (3), (6) and (9) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

CPI Score and Day to Day Operations Measures (Robustness Test: Region)

Dependent Variable	1 CPIscore	2 CPIscore	3 CPIscore	4 CPIscore	5 CPIscore	6 CPIscore	7 CPIscore	8 CPIscore	9 CPIscore
CrossBorderTrade	0.0408**	0.0427**	0.0473***						
	(0.0187)	(0.0185)	(0.0157)						
AccessToElectricity				0.0516***	0.0544***	0.0878***			
				(0.0180)	(0.0168)	(0.0221)			
EaseOfPayingTaxes							0.0618**	0.0633*	0.0831***
							(0.0313)	(0.0329)	(0.0303)
Constant	41.48***	41.59***	45.75***	40.62***	40.48***	41.77***	40.49***	40.61***	43.19***
	(1.324)	(1.462)	(2.995)	(1.310)	(1.360)	(2.514)	(1.962)	(1.934)	(4.259)
Observations	1,180	1,180	738	1,180	1,180	738	1,180	1,180	738
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
RegionFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IncomeFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 1,239 observations across 177 countries between 2012 and 2018. Columns (1)-(3) report results for the *CrossBorderTrade*, columns (4)-(6) report results for the *AccessToElectricity*, and columns (7)-(9) report results for the *EaseOfPayingTaxes*. These three are measures for the ease of conducting standard day to day operations, as extracted from the "Ease of Doing Business Index DataBase" from World Bank. *CPIscore* is the corruption perception index extracted from Transparency International. Columns (1), (4), and (7) only include region fixed-effects, columns (2), (5), and (8) include both year- and region-fixed effects, and columns (3), (6) and (9) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix 1

Proof A

$v(z) > 0$ for all $z < z^*$.

$v'(z) = \frac{\alpha}{z^*} \cdot \left(\frac{z}{z^*}\right)^{\alpha-1} > 0$ for all $z < z^*$.

$v''(z) = \frac{\alpha \cdot (\alpha-1)}{(z^*)^2} \cdot \left(\frac{z}{z^*}\right)^{\alpha-2} > 0$ for all $z < z^*$.

Proof B

Optimization problem is as follows:

$$\max_{z} \quad y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right) - b - [g \cdot v(z) \cdot R]$$

$$s.t. \quad b = y + z$$

Taking the first-order condition under constraint and setting the result to zero yields the following:

$$-\left(1 + r_{g=0}\right) + \left(1 + r_{g>0}\right) - \left[g \cdot \frac{\alpha}{z^*} \cdot \left(\frac{z}{z^*}\right)^{\alpha-1} \cdot R\right] = 0$$

$$\therefore \; \tilde{z} = \left[\frac{(z^*)^{\alpha} \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}}$$

We further check the second-order condition:

$$\frac{d^2 Profit}{dz^2} = -(g) \cdot \frac{(\alpha) \cdot (\alpha - 1)}{(z^*)^2} \cdot \left(\frac{z}{z^*}\right)^{\alpha-2} \cdot R < 0$$

<u>Proof C</u>

Let w be the proportion of firms in the economy that gets convicted.

When a single firm invests their full investment budget in gray investment projects, we yield the following expected payoff function:

$$E(Payoff) = b \cdot r_{g>0} - g \cdot R$$

Assuming that $b \cdot r_{g>0} - g \cdot R > 0$, this implies that $E(Profit) > 0$ if firm invests their full investment budget in gray projects.

Thus, all firms will invest their full investment budget in gray projects as $E(Profit) > 0$.

We assumed that when firms invest their full investment budget in gray project, it leads to a definite conviction.

Hence, if $E(Profit) > 0$, we expect $w = 1$ in the real world.

However, in real-world, we do not observe $w = 1$.

Therefore, $b \cdot r_{g>0} - g \cdot R > 0 < 0$ must be true.

<u>Proof D</u>

The aggregate gray project investments under two single-firm ecosystem is as follows:

$$2 \cdot \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}}$$

The aggregate gray project investments in a competitive similar two-firm market is as follows:

$$\left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R \cdot \left(1 - v_2(z_2) \cdot \tau_{2,1}\right)} \right]^{\frac{1}{\alpha-1}} + \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R \cdot \left(1 - v_1(z_1) \cdot \tau_{1,2}\right)} \right]^{\frac{1}{\alpha-1}}$$

$$= \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}} \cdot \left\{ \left[\frac{1}{\left(1 - v_2(z_2) \cdot \tau_{2,1}\right)} \right]^{\frac{1}{\alpha-1}} + \left[\frac{1}{\left(1 - v_1(z_1) \cdot \tau_{1,2}\right)} \right]^{\frac{1}{\alpha-1}} \right\}$$

$$\because \; 0 < v_i(z_i) \cdot \tau_{i,j} < 1$$

$$\Rightarrow \; 0 < \left(1 - v_i(z_i) \cdot \tau_{i,j}\right) < 1$$

$$\Rightarrow \; \frac{1}{\left(1 - v_i(z_i) \cdot \tau_{i,j}\right)} > 1$$

$$\Rightarrow \; \left[\frac{1}{\left(1 - v_i(z_i) \cdot \tau_{i,j}\right)} \right]^{\frac{1}{\alpha-1}} > 1$$

$$\therefore \; \left\{ \left[\frac{1}{\left(1 - v_2(z_2) \cdot \tau_{2,1}\right)} \right]^{\frac{1}{\alpha-1}} + \left[\frac{1}{\left(1 - v_1(z_1) \cdot \tau_{1,2}\right)} \right]^{\frac{1}{\alpha-1}} \right\} > 2$$

<u>Proof E</u>

Recall that the aggregate gray project investments in a competitive two-firm market is as follows:

$$\left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}} \cdot \left\{\left[\frac{1}{(1 - v_2(z_2) \cdot \tau_{2,1})}\right]^{\frac{1}{\alpha-1}} + \left[\frac{1}{(1 - v_1(z_1) \cdot \tau_{1,2})}\right]^{\frac{1}{\alpha-1}}\right\}$$

The aggregate gray project investments in a collusive similar two-firm market is as follows:

$$\left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot [R \cdot (1 - v_2(z_2) \cdot \tau_{2,1}) + R \cdot \tau_{1,2} \cdot (1 - v_2(z_2))]}\right]^{\frac{1}{\alpha-1}}$$

$$+ \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot [R \cdot (1 - v_1(z_1) \cdot \tau_{1,2}) + R \cdot \tau_{2,1} \cdot (1 - v_1(z_1))]}\right]^{\frac{1}{\alpha-1}}$$

$$= \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}}$$

$$\cdot \left\{\left[\frac{1}{(1 - v_2(z_2) \cdot \tau_{2,1}) + \tau_{1,2} \cdot (1 - v_2(z_2))}\right]^{\frac{1}{\alpha-1}}\right.$$

$$\left. + \left[\frac{1}{(1 - v_1(z_1) \cdot \tau_{1,2}) + \tau_{2,1} \cdot (1 - v_1(z_1))}\right]^{\frac{1}{\alpha-1}}\right\}$$

$$\because \tau_{i,j} \cdot \left(1 - v_j(z_j)\right) > 0$$

$$\Rightarrow \left(1 - v_j(z_j) \cdot \tau_{j,i}\right) < \left(1 - v_j(z_j) \cdot \tau_{j,i}\right) + \tau_{i,j} \cdot \left(1 - v_j(z_j)\right)$$

$$\Rightarrow \frac{1}{\left(1 - v_j(z_j) \cdot \tau_{j,i}\right)} > \frac{1}{\left(1 - v_j(z_j) \cdot \tau_{j,i}\right) + \tau_{i,j} \cdot \left(1 - v_j(z_j)\right)}$$

$$\Rightarrow \left[\frac{1}{\left(1 - v_j(z_j) \cdot \tau_{j,i}\right)}\right]^{\frac{1}{\alpha-1}} > \left[\frac{1}{\left(1 - v_j(z_j) \cdot \tau_{j,i}\right) + \tau_{i,j} \cdot \left(1 - v_j(z_j)\right)}\right]^{\frac{1}{\alpha-1}}$$

$$\therefore \left\{ \left[\frac{1}{(1 - v_2(z_2) \cdot \tau_{2,1})}\right]^{\frac{1}{\alpha-1}} + \left[\frac{1}{(1 - v_1(z_1) \cdot \tau_{1,2})}\right]^{\frac{1}{\alpha-1}} \right\}$$

$$> \left\{ \left[\frac{1}{(1 - v_2(z_2) \cdot \tau_{2,1}) + \tau_{1,2} \cdot (1 - v_2(z_2))}\right]^{\frac{1}{\alpha-1}} \right.$$

$$\left. + \left[\frac{1}{(1 - v_1(z_1) \cdot \tau_{1,2}) + \tau_{2,1} \cdot (1 - v_1(z_1))}\right]^{\frac{1}{\alpha-1}} \right\}$$

Proof F

$$\because 0 \leq \frac{\tilde{z}_1}{z^*} \leq 1$$

$$\Rightarrow 0 \leq \left(1 - \frac{\tilde{z}_1}{z^*}\right) \leq 1$$

$$\Rightarrow \frac{1}{e} \leq e^{-\left(1 - \frac{\tilde{z}_1}{z^*}\right)} \leq 1$$

$$\Rightarrow \alpha \geq \omega$$

$$\therefore \left(\frac{z}{z^*}\right)^{\alpha} \leq \left(\frac{z}{z^*}\right)^{\omega}$$

<u>Proof G</u>

$$\because \tilde{z} = \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}}$$

$$= \left[\frac{z^* \cdot \left(r_{g>0} - r_{g=0}\right)}{g \cdot R} \cdot \frac{(z^*)^{\alpha-1}}{\alpha}\right]^{\frac{1}{\alpha-1}}$$

$$= \left(a \cdot \frac{b^d}{d+1}\right)^{\frac{1}{d}},$$

where:

$$a = \frac{b \cdot \left(r_{g>0} - r_{g=0}\right)}{g \cdot R} > 0$$

$$b = z^* > 0$$

$$d = \alpha - 1 > 0$$

$$\Rightarrow \frac{d\tilde{z}}{d\alpha} = \frac{-b \cdot (d+1)^{-\frac{d+1}{d}} \cdot a^{\frac{1}{d}} \cdot \left[(d+1) \cdot \log_e\left(\frac{a}{d+1}\right) + d\right]}{d^2},$$

where:

$$\frac{-b \cdot (d+1)^{-\frac{d+1}{d}} \cdot a^{\frac{1}{d}}}{d^2} < 0$$

Next, we show the condition that will make the following hold:

$$\left[(d+1) \cdot \log_e\left(\frac{a}{d+1}\right) + d\right] > 0$$

$$\Rightarrow \frac{z^* \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R} > e^{-\left(\frac{\alpha-1}{\alpha}\right)} \cdot \frac{(z^*)^{\alpha-1}}{(z^*)^{\alpha-1}}$$

$$\Rightarrow \tilde{z} > z^* \cdot e^{\frac{-1}{\alpha}}$$

$$\Rightarrow \frac{1}{\log_e\left(\frac{z^*}{\tilde{z}}\right)} > \alpha$$

The above condition will result in $\frac{d\tilde{z}}{d\alpha} < 0$. Coupled with Proof F where α is decreasing across time, we see that the firm's optimal amount of gray project investment will increase in the later time period.

Furthermore, given that α and $\tilde{z}$ decreases and increases, respectively, in the subsequent time period, this implies that the condition having held in the present time period will continue to hold in the subsequent time period.

Proof H

Following from Proof G, we can easily see that $\frac{d\tilde{z}}{d\alpha} > 0$ when the following condition holds:

$$\frac{1}{\log_e\left(\frac{z^*}{\tilde{z}}\right)} < \alpha$$

Coupled with Proof F where α is decreasing across time, we see that the firm's optimal amount of gray project investment will decrease in the later time period. As both sides of the condition will decrease in the subsequent time period, it is not guaranteed that fulfilling the condition in the present time period will allow the condition to be met in the subsequent time period.

<u>Proof I</u>

Assuming that the following condition holds:

$$\frac{z^*}{\tilde{z}} > e^1$$

$$\Rightarrow \log_e\left(\frac{z^*}{\tilde{z}}\right) > 1$$

$$\Rightarrow \frac{1}{\log_e\left(\frac{z^*}{\tilde{z}}\right)} < 1$$

$$\because \alpha > 1$$

$$\therefore \frac{1}{\log_e\left(\frac{z^*}{\tilde{z}}\right)} < \alpha$$

Hence, we show that if the initial condition hold, the condition given in Proposition 10 will always hold.

Proof J

Note that the optimal amount of gray investment project accounting for business-friendly investments by regulators is given as follows:

$$\tilde{z} = \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - \psi r_{g=0}\right)}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}}$$

$$\frac{\partial \tilde{z}}{\partial \psi} = -\frac{(z^*)^\alpha \cdot r_{g=0}}{(\alpha-1) \cdot (\alpha \cdot g \cdot R)} \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - \psi r_{g=0}\right)}{\alpha \cdot g \cdot R} \right]^{\frac{2-\alpha}{\alpha-1}} < 0$$

Internalizing the Costs of Gray Project Investments by Firms: *Regbonds*

Abstract

This paper is based on the idea of gray project investments and provides a basic model to allow decision makers to better understand the underlying characteristics of gray project investments. This paper then takes a step further at the macro-level and shows that there exists overinvestments of gray projects at the aggregate level. Furthermore, information asymmetry results in an inefficient allocation of deterrence investments by regulators. This paper presents a novel solution, the *Regbonds*. We show that *Regbonds* help to reduce aggregate gray project investments under the mandated setting by helping firms internalize the external costs of decision making. We also show that under the voluntary setting, *Regbonds* function as a signaling mechanism. This allows for a more efficient allocation of deterrence investments by regulators and helps to bring aggregate gray project investments closer towards optimal.

1. Introduction

Information asymmetry and the resulting adverse selection is a problem that has consistently received attention among academics and researchers ever since it was first coined in the 1970s (Akerlof, 1970; Spence, 1973; Stiglitz, 1975). The economics of crime and punishment among individuals have also been researched upon ever since the seminal paper by Becker (1968). However, there has been a lack of research concerning gray project investments at the macro level. Chapter 1 provides a sound mathematical model that helps to explain firm behavior concerning gray project investments.

This paper provides an extension by showing that firms will overinvest in gray projects resulting in an aggregate that is suboptimal. This problem is exacerbated by the inefficient allocation of deterrence investments by regulators due to asymmetric information. The paper proceeds to provide a novel solution, the *Regbonds*. The *Regbonds* function like a bond, where the company that posts it will receive cash while the counterparty will receive coupon payments in return for putting up the money. However, unlike traditional bonds, *Regbonds* will not be used to finance firm's capital investments. Instead, *Regbonds* will be set aside in escrow and the bondholders will receive their principal upon maturity given that no trigger event occurs. In the case of *Regbonds*, the trigger event will be when the firm gets convicted for their gray project investments. This implies that the *Regbonds* will be used to pay off the financial loss arising from the trigger event.

This paper then goes on to show that under a compulsory setting (i.e. posting of *Regbonds* are mandated by law) and given that certain conditions hold, firms will internalize the external costs of their gray project investments. This helps to reduce the aggregate overinvestments within the economy. Our results are robust as the amount of gray project investments under mandate will tend towards the optimal gray project investments as *Regbonds* posting amount increases. However, a potential issue that might arise is it might result in suboptimal behavior where firms underinvest in gray projects due to the posting of *Regbonds*.

We go on to show that under a voluntary setting (i.e. firms get to decide whether they want to post *Regbonds*), it helps to solve the issue under the compulsory setting. The notion is that under the voluntary setting, we show that under certain conditions, good

firms will choose to post *Regbonds* while bad firms will choose not to. This in turn allows regulators to more efficiently allocate deterrence investments towards bad firms. This results in a snowballing effect where bad firms, in response to increased regulatory scrutiny, will reduce their gray project investments and will find it feasible to post *Regbonds*. This further allows regulators to engage in an even more efficient allocation of deterrence investments, and the process repeats. We show that this will result in two eventual outcomes, where either (i) all firms in the ecosystem will post *Regbonds* or (ii) only a portion of all firms choose to post *Regbonds*. Under the first scenario, all firms will have internalized the external costs of their decisions and the aggregate gray project investments in the ecosystem will decrease and tend towards optimal. Under the second scenario, good firms that choose to post *Regbonds* will have internalized the external costs of their decisions while bad firms will have increased regulatory scrutiny. Both scenarios will reduce the aggregate gray project investments in the ecosystem. We note that the decrease in aggregate gray project investments under scenario (i) is more than the decrease in scenario (ii). A key assumption used in our paper is that incentives between shareholders and managers are perfectly aligned and this ensures our analysis at the macro level to be mathematically tractable. In chapter 3, we relax this assumption and analyze the impact of *Regbonds* on gray project investments by firms.

The rest of the paper is organized as follows. Section 2 is the literature review. Section 3 lays out the basic model set-up and the problem arising from gray project investments. Section 4 introduces *Regbonds* and conducts the analyses under a compulsory and voluntary setting which helps to solve the problem laid out in section 3. Section 5 conducts empirical analyses. Section 6 concludes.

2. Literature Review

The idea underlying information asymmetry was founded by Akerlof (1970) when he used the term "lemons" to refer to bad cars, where car buyers possess different information set than car sellers. This incentivizes car sellers to sell goods that are below the average market quality. Therefore, car buyers are unable to differentiate between lemons and good cars, and this results in sellers of good cars unable to receive prices above the market

average. Spence (1973) extended on this notion to the signaling of employees in the job market. Specifically, employees are modelled as uncertain investments for firms as the employers cannot ascertain the underlying productivity of the employee at the point of hire. He suggests this is the reason behind wage stickiness in certain low-paying jobs due to an unwillingness to bid up wages. Stiglitz (1975) expounded on the theory of information asymmetry with the theory of screening. He utilized general equilibrium models and used it to explain the allocation of resources towards education. These papers triggered a wave of literature on information asymmetry that models information asymmetry under different settings (Grossman & Stiglitz, 1980; Myers & Majluf, 1984; Grinblatt & Hwang, 1989; Greenwald & Stiglitz, 1990; Stiglitz & Weiss, 1992; Stiglitz, 2002). Furthermore, researchers also empirically studied the theory of information asymmetry under different markets, such as the truck market (Bond, 1982), the life insurance market (Cawley & Philipson, 1999), the dating and employment market (Tabarrok, 1994), and IPO underpricing (Booth & Chua, 1996).

In our paper, we contribute to the vast information asymmetry literature by modelling information asymmetry within the setting of gray project investments. We show that regulators are unable to effectively allocate deterrence investments across firms due to information asymmetry. This leads to over deterrence and under deterrence of good and bad firms, respectively.

Given the costs associated with information asymmetry and adverse selection, a wave of literature has focused on strategies that good firms can employ to differentiate themselves from bad firms. These strategies can be divided into three broad categories, (i) building reputation, (ii) providing guarantee, and (iii) seeking third party certification. First, in reputation building, firms are required to invest a portion of their investment budget in developing a reputation that they are a good firm. This differentiates themselves from the bad firms (Klein & Leffler, 1981; Shapiro, 1982; Shapiro, 1983; Diamond, 1989). Second, in providing guarantee (or warranty), firms are signaling to prospective clients that their product is of a higher quality. This helps to differentiate because the strategy is more expensive for bad firms to duplicate (Grossman, 1981; Wiener, 1985; Gal-Or, 1989). Third, good firms might incur costs to receive certification by a recognized third-party organization such as reputable auditing firms, bond rating agencies, and professional

licensing bodies. With this certification, good firms will be able to differentiate themselves from bad firms (Carter & Manaster, 1990; Anderson, Daly, & Johnson, 1999).

In response, our paper contributes to this literature by introducing a new method to combat the adverse selection problem arising from information asymmetry, the *Regbonds*. We propose that *Regbonds* help to solve the problem by serving as a signaling mechanism that allows regulators to differentiate between good and bad firms. The underlying mechanism of *Regbonds* is most similar to "providing guarantees", where firms that choose to post *Regbonds* will incur additional costs given that they are a bad firm duplicating the strategy of a good firm. However, the key difference is that guarantees is a wealth transfer from firms to consumers whereas *Regbonds* is a wealth transfer from firms to third parties that experience losses arising from the overinvestments of gray projects by firms. Furthermore, *Regbonds* help firms internalize the external costs of their decision making when it comes to gray project investments. This also provides an avenue for future research where derivatives of *Regbonds* can be constructed and purchased by external investors that are willing to bear the risks. This allows *Regbonds* to create a market for efficient monitors that can potentially deter firms from overinvesting in gray project investments.[1]

Our paper also contributes to the large literature on crime and punishment that was triggered by the seminal paper by Becker (1968). In his paper, he proposes that an individual will choose to commit and offense only if the expected utility to him exceeds the utility he could achieve by spending his time and resource at other activities. He uses this idea to determine optimal policies that can minimize criminal behavior among individuals. Block & Heineke (1975) went a step further by accounting for multi-attributes of choice among individuals and argued that empirical determination is required to provide useful policy recommendations.

A key result from Becker (1968) is that deterrence for individual crime is a function of the severity of penalty and probability of conviction. This led to conflicting views within the literature. On the one hand, some found that a higher certainty of punishment was more

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[1] However, derivatives of *Regbonds*' are not the focus of this paper. This might make for an interesting follow-up paper.

significant in deterring criminal activities (Ehrlich, 1973; Tittle & Rowe, 1974; Myers Jr., 1983; Grogger, 1991). On the other hand, others found that severity of punishment is a stronger deterrent (Cornwell & Trumbull, 1994; Ehrlich, 1996). Some documented that the deterrent effect of severity is more prominent when it concerns more serious offenses such as assault, drug use (Witte, 1980) and even murder (Ehrlich, 1975); and that severity is a stronger deterrent in the long-run (Garoupa, 1997). However, there is a lack of papers that analyzes gray project investments within firms (Shleifer & Wolfrenzon, 2002). A paper similar to ours is Simpson (2002), where she looked at institutional misconduct at the firm-level. In addition, Holt (2018) and Freilich & Newman (2018) analyzed the interaction between law enforcers and the firm's criminal behavior. However, the analyses underlying both strands of literature took a more qualitative approach whereas our paper is grounded in mathematical models to illustrate gray project investment behavior at the firm level.

Chapter 1 lays out a sound mathematical model that sheds novel insights and helps to explain real-world behavior of firms. In our paper, we focus on bridging the gap of information asymmetry at the macro level and show how *Regbonds* can help to act as a signal to active regulators and also mitigate aggregate gray project investments in the economy.

3. The Problem

This section begins by laying out the model used for analysis followed by a discussion on the two most prominent issues with gray project investments in the current ecosystem: (i) overinvestment in gray project investments and (ii) inefficient allocation of deterrence investment by regulators.

3.1 Model Set-up and Assumptions

The core assumption used in this paper is that the interests between shareholders and managers of a firm is perfectly aligned. The purpose for such an assumption is to keep the analysis mathematically tractable. We note that in reality this is not true and the study of

agency theory forms a big literature on its own, therefore the analysis of agency costs within our framework will be described in detail in Chapter 3.

We begin our analysis by placing our focus on the optimal gray project investment from the firm's perspective. The firm is defined to have a fixed investment budget constraint which the firm will allocate between two investment projects. One of the investment project is a legal investment project while the other is a gray investment project with probability g of the project turning out to be illegal. The budget constraint is as follows:

$$b = y + z,$$

where b is the fixed investment budget constraint, y is the investment in the legal investment project, and z is the investment in the gray investment project. The expected return on investment in $P_{g=0}$ and $P_{g>0}$ is assumed to be known ex-ante and is denoted by $r_{g=0}$ and $r_{g>0}$ respectively.[2] This yields the *Expected Revenue* expression as follows:

$$E(Revenue) = y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right).$$

Furthermore, for the gray project investment undertaken by the firm, given that the project turns out to be illegal, there is a likelihood of conviction. We define this as the conviction probability and the probability function is denoted as $v(z)$ and is defined as follows:

$$v(z) = \begin{cases} \left(\dfrac{z}{z^*}\right)^{\alpha} & , \quad z < z^* \text{ and } \alpha > 1 \\ 1 & , \quad z \geq z^* \end{cases},$$

where z is the gray project investment, z^* is the upper-limit of gray project investments, and α is a firm specific variable that captures the firm's characteristics.[3] In addition, a firm that is convicted for their gray project investments will be subjected to a financial loss denoted as R. Figure 1 plots the costs to the firm undertaking gray project investments.

[Place Figure 1 about here]

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[2] The implicit assumption is that returns from gray investment project exceed those from the legal investment project.

[3] Gray project investments exceeding z^* will result in a definite probability of conviction, given that the project turns out to be illegal.

We can see from the diagram that the implicit assumption underlying our model is that the firm will fully utilize his fixed investment budget. Coupling this with the earlier *Expected Revenue* expression, we plot Figure 2 that shows the returns for the firm.

[Place Figure 2 about here]

> Proposition 1: Given that the firm gets convicted, the implicit result from our model is that the firm will definitely yield negative return. Conversely, if the firm does not get convicted, the implicit result is that the firm will definitely yield a positive return.
>
> (Proof A)

Taken together, we yield the following *Expected Return* expression for the firm:

$$Expected\ Return = \frac{y r_{g=0} + z r_{g>0} - Rg\left(\frac{z}{z^*}\right)^{\alpha}}{b}.$$

We define the following optimization problem:

$$\max_{z} \quad E(Return)$$

$$s.t. \quad b = y + z.$$

Solving the optimization problem, we determine the optimal investments in legal and gray investment projects, denoted as $\tilde{y}$ and $\tilde{z}$ respectively, as follows:

$$\tilde{y} = b - \tilde{z}$$

$$\tilde{z} = \left[\frac{(z^*)^{\alpha} \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha - 1}}.$$

(Proof B)

3.2 Overinvestment in Gray Projects

We document in the prior section that all firms will optimally have some investment budget allocated to gray investment projects. This section shows that firms will overinvest

in gray investment projects due to a failure in internalizing the external costs of their actions.

First, we define financial loss (i.e. R) in greater detail. R is the financial loss that occurs given that the firm is convicted of their gray project investment. This financial loss can take many forms. Some examples are fines from regulators, reputational loss, loss of future revenue and profits, loss in market value, and remediation costs.

Given that it is not a single-firm ecosystem, there exists multiple stakeholders within the ecosystem. Some examples of these stakeholders are debtholders, customers, suppliers, and taxpayers. Due to the interconnectedness of different stakeholders within the same ecosystem, we see that when a financial loss event occurs, a portion of the financial loss is borne by these other stakeholders. This is an inefficient system as these stakeholders need to bear the cost of the decisions made by the firm. For example, when the firm suffers from reputational loss, the reputation of those in her upstream and downstream are inevitably affected as these suppliers and customers are perceived to be linked to the event firm. Another case example would be the subprime mortgage crisis, where the government bailed out the banks with taxpayers' money.

Hence, we propose that firms will only bear a portion μ of the financial loss that occurs when the firm gets convicted. The remaining $(1 - \mu)$ portion of the financial loss is borne by other stakeholders within the ecosystem.[4]

Following the result in section 3.1, we show that the optimal allocation of investment budget for the firm when they fail to internalize the full costs of their decision is as follows:

$$
\begin{aligned}
\tilde{y}_{ext} &= b - \tilde{z}_{ext} \\
\tilde{z}_{ext} &= \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot \mu \cdot R} \right]^{\frac{1}{\alpha-1}},
\end{aligned}
$$

where $\tilde{y}_{ext}$ and $\tilde{z}_{ext}$ are the firm's optimal investments in legal and gray investment projects when the firm fails to fully internalize the costs of their decisions, respectively.

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[4] For mathematical tractability, we further require the following restriction where $0 \leq \mu \leq 1$ and we term μ as the internalization variable.

Proposition 2: When a firm fails to fully internalize the costs of their decisions, we see that the firm will overinvest in gray investment projects where

$$\tilde{z} < \tilde{z}_{ext}$$

(Proof C)

Therefore, the firm will overinvest in gray investment projects when there exists other stakeholders in the ecosystem to help bear the costs of their decisions. At this point, we will like to emphasize that the author's proposal is that such an overinvestment is not the fault of the firm. This is simply how the ecosystem is built and the firm is only acting in their own best interests, the absolute rule of nature. The solution will then be to provide a novel system that allows firms to better internalize the costs of their actions as will be elaborated in greater detail in section 4.

3.3 Inefficient Allocation of Deterrence Investment by Regulators

In this section, we regard regulators as taking an active role in mitigating gray project investments from firms. Given that our definition of z^* makes it an accurate proxy for the conviction probability density function, the following relationship holds true:

$$For\ all\ z_1^* \geq z_2^* \Rightarrow v_{z_1^*}(z) \leq v_{z_2^*}(z)\ for\ all\ values\ of\ z.$$

This implies that active regulators can allocate their deterrence investment budget towards reducing the firm's z^* and this will lead to an increase in the firm's likelihood of conviction at all levels of z. This takes the following form:

$$z^* = z_0^*\left(1 - \Delta z_{reg}^*\right)$$

$$\Delta z_{reg}^* = \begin{cases} \left(\dfrac{m}{m^*}\right)^{1-\theta} & ,\ m < m^*, \\ 1 & ,\ m \geq m^* \end{cases} \quad 0 < \theta < 1,$$

where z_0^* is equivalent to the firm's default z^* when the regulator do not take an active role in mitigating firm's gray project investments, Δz_{reg}^* is the percentage change in the firm's z^* when investments are made by the active regulator, m is the deterrence investments

made by the active regulator, m^* is the upper-limit of deterrence investments that could be made by the active regulator to fully deter the firm's gray project investment, θ is the efficiency of the regulator's investment where a larger θ implies a more efficient active regulator (i.e. a given dollar investment from the active regulator corresponds to a larger reduction in the firm's z^*).

Furthermore, we highlight that an increase in deterrence investments (as defined in this paper) from the regulators do not result in an increase in regulatory reporting costs by the firm.[5] An increase in deterrence investments from regulators imply an increase in resources spent on gathering more information on the activities of the firm. More information could be gathered when more resources are expended to scrutinize the actions undertaken by the firm. On the one hand, such scrutiny on firms with heavy investments in gray projects would result in a significantly higher likelihood of conviction for these firms. On the other hand, the impact on firms with little or no investment in gray projects are much lower. This notion is implicitly incorporated into our model, where the effective return from gray projects decreases when deterrence investment increases; however, a similar increase in deterrence investment has little to no impact on the effective return from legal projects. Our hypotheses here are supported by the empirical tests that we had conducted in Chapter 1.[6] That said, we note that incorporating regulatory reporting costs would be an interesting extension to the paper as well. This is because regulatory reporting could be an alternative strategy that regulators employ to ensure companies are compliant. This will be something that we will consider in future extension papers.

In a single firm economy, the regulator's optimal decision is trivial and the regulator only needs to invest their full deterrence investment budget to reduce z^*. However, the decision process becomes more complicated in the real world where there exists multiple firms within the ecosystem. For simplicity of analysis, we will begin with a two-firm

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[5] Some examples of deterrence investments would be to hire officers to stay by the side of all the firm's employees/decision-makers 24/7, or to fully scrutinize every single contract made by the firm. This can deter the firm from engaging in gray project investments as they will be caught if they choose to engage in such projects (i.e. $z^* = 0$), but the associated costs to achieve this in the real-world is expectedly large.

[6] In Chapter 1, we showed that an increase in investments from governments that improved the effective return from legal projects (but did not affect the effective return from gray projects) led to a reduction in optimal gray project investments.

ecosystem under symmetric information to yield the optimal decision function by regulators. We will then extend the model to that of an asymmetric information setting and finally extend the implication of our results to a multi-firm ecosystem. We first define a good firm and a bad firm and they are identical apart from their conviction probability function and the amount of financial loss they internalize in their decision-making process. Specifically:

$$z^*_{good} = z^*_{0,good}\left(1 - \left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right), \qquad 0 < \theta < 1,$$

$$z^*_{bad} = z^*_{0,bad}\left(1 - \left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right), \qquad 0 < \theta < 1,$$

where z^*_{good} and z^*_{bad} is the z^* for the good and bad firm, respectively; $z^*_{0,good}$ and $z^*_{0,bad}$ is the default z^* for the good and bad firm, respectively; m_{good} and m_{bad} is the deterrence investment allocated to the good and bad firm by the regulator, respectively; θ is the efficiency of the regulator investment, m^* is the upper limit of deterrence investment that could be made by the regulator to fully deter gray project investment, and this is sufficiently large. Next, as we have assumed a two-firm ecosystem, the regulator needs to divide the deterrence investment budget between the good firm and the bad firm. The budget constraint of the regulator is given by:

$$m = m_{good} + m_{bad},$$

where m is the deterrence investment budget.

As defined earlier, both good and bad firms are identical apart from their conviction probability density function and internalization variable. We define the differences as follows:

$$z^*_{0,good} < z^*_{0,bad},$$

$$\mu_{good} > \mu_{bad},$$

where μ_{good} and μ_{bad} are the internalization variable for the good and bad firm respectively. The first relationship arises from our assumption that a bad firm will have a

lower conviction probability than the good firm at all levels of gray project investments. The second relationship is similarly derived where a bad firm will internalize less of the financial loss. This implies more of the financial loss will be borne by external stakeholders, relative to the good firm. The optimal gray project investment for the firms are thus:

$$\tilde{z}_i = \left[\frac{\left(z_{0,i}^* \left(1 - \left(\frac{m_i}{m^*} \right)^{1-\theta} \right) \right)^{\alpha} \cdot \left(r_{g>0} - r_{g=0} \right)}{\alpha \cdot g \cdot R \cdot \mu_i} \right]^{\frac{1}{\alpha - 1}}, \qquad where\ i = bad, good.$$

Based on our previously defined relationship, we can derive the following relationship that justifies the notion that a bad firm will invest a higher amount in gray project investments:

$$\tilde{z}_{bad} > \tilde{z}_{good}.$$

From the regulator's perspective, they minimize the total gray project investments from both firms, given by the following optimization problem function:

$$\min_{m_{good}, m_{bad}} \tilde{z}_{good} + \tilde{z}_{bad}$$

$$s.t. \quad m = m_{good} + m_{bad}.$$

Solving the optimization function yields the following relationship:

$$\left(\frac{\mu_{bad}}{\mu_{good}} \right)^{\frac{1}{\alpha-1}} \cdot \left(\frac{z_{0,good}^*}{z_{0,bad}^*} \right)^{\frac{\alpha}{\alpha-1}} = \left(\frac{m_{good}}{m_{bad}} \right)^{\theta} \cdot \left[\frac{1 - \left(\frac{m_{bad}}{m^*} \right)^{1-\theta}}{1 - \left(\frac{m_{good}}{m^*} \right)^{1-\theta}} \right]^{\frac{1}{\alpha-1}}.$$

(Proof D)

Proposition 3: In an ecosystem with symmetric information, regulators are able to accurately determine the firm's z_0^* and μ for all firms, and will allocate a greater portion of their deterrence investment in bad firms, relative to good firms.

Our result holds important implication for regulators as being able to accurately allocate the deterrence investment budget is key to minimizing the total gray project investment of the ecosystem. Specifically, it is essential for regulators to allocate a greater portion of their deterrence investment budget in firms that tend to have a higher optimal gray project investment (i.e. firms with a higher default z^*).

> Proposition 4: The regulator might not be able to directly affect the amount of financial losses internalized by the firm, but the regulator can still indirectly target firms with a low internalization variable by allocating more deterrence investment budget towards reducing the firm's z^*.

Even if $z^*_{0,good} = z^*_{0,bad}$, so long as the firms internalize different amounts of the financial loss arising from their decision function, regulators with symmetric information of the firm's internalization variable will be able to allocate deterrence investment optimally to minimize the total gray project investment of the ecosystem. The regulator does so by consciously changing the firm's initially identical conviction probability function. A bad firm will be allocated more deterrence investment. This will lead to a greater reduction in its z^*. This implies that the bad firm will have a higher conviction probability function than the good firm at all levels of gray project investments.

Hence, our results imply that although the regulator might not be able to directly affect the amount of financial losses internalized by each firm, the regulator will still be able to minimize the total gray project investments of the ecosystem. The regulator does so by indirectly affecting the firm's gray project investments via their conviction probability density function.

The premise of our earlier analysis is that symmetric information exists within the ecosystem. However, in the real-world with a system of asymmetric information, the firm's default z^* is only determined ex-post (i.e. after the firm has been successfully convicted for their gray project investments). In such a setting, regulators would only be able to collect information concerning the full extent of the firm's initial gray project investments and use that to determine the firm's default z^*. Hence, it is important to determine the optimal allocation of deterrence investment by regulators in an asymmetric

information setting (i.e. the real-world setting). We follow the assumptions from above but allow for a system with asymmetric information. In such a setting, the regulators are unable to differentiate between the good and bad firms and thus, the unbiased prior that the regulators have on the underlying nature of the firm is that both firms have the same default z^*. The regulators will then optimally allocate their deterrence investment between firm 1 and 2 based on this unbiased prior where:

$$z_{0,bad}^* = z_{0,good}^*,$$

$$\mu_{good} = \mu_{bad}.$$

Applying this unbiased prior into the above optimization solution yields the solution within an asymmetric setting where the regulator will allocate their deterrence investment budget equally among all the firms. Hence, the implication is that the deterrence investment budget from the regulators are still not efficiently utilized where good firms and bad firms are over-deterred and under-deterred, respectively. The total gray project investments within the ecosystem will not be minimized in an asymmetric information setting relative to that of a symmetric information setting. The solution will then be to provide a novel system that allows firms to signal to regulators on the underlying nature of the firm. This allows the regulator to more efficiently allocate a greater portion of their deterrence investment budget towards the bad firms, as will be elaborated in greater detail in section 4.

4. The Solution: *Regbonds*

In this section, we propose a novel solution that puts in place a system within the ecosystem that helps firm internalize a greater portion of the financial losses arising from their decisions. Our solution also helps regulators allocate their deterrence investment budget more efficiently. Taken together, the motivation underlying *Regbonds* reduces and minimize the total gray project investments within the ecosystem by calling for greater accountability and transparency of the firm's decision-making process.

We will first provide a description on the mechanics of the *Regbonds* and the key assumptions made in our analysis. We then discuss the function of *Regbonds* and how

Regbonds achieve its purpose under a compulsory setting (i.e. the implementation of *Regbonds* is written into law by regulators and must be posted by firms) and a voluntary setting (i.e. the posting of *Regbonds* is voluntary). We will also discuss the benefits and costs of both settings within each respective section.

4.1 *Regbonds*: The Mechanics and Assumptions

The *Regbond* functions like a bond: the company that posts it will receive cash at the beginning while bondholders will receive coupon payments. The cash and coupon payment will be set aside and paid out to the bondholders upon maturity. However, no cash will be paid out if the default event occurs. The default event is when the firm gets convicted and the *Regbond* will be triggered to pay off the financial loss.

Furthermore for *Regbond*, the party putting up cash for the bond will be the posting firm while the party that pays the coupon payment will be the regulator and/or other external stakeholders of the ecosystem. This means that the posting firm have an initial endowment, and posting *Regbonds* essentially means the firm will put aside a portion of their endowment to earn an interest payment in return for the risk of a financial loss event occurring. This is laid out specifically in Figure 3. This is a set-up where we assume that there exists no agency problems between decision makers (i.e. managers and employees) and shareholders (i.e. owners). In the real-world, where agency problems are prevalent, we propose that the party putting up cash for the bond will be the decision makers (i.e. firm managers and employees) while the party that puts up the coupon payment will be the parties that enjoy the benefits brought about by *Regbonds* (i.e. regulators, shareholders and/or other external stakeholders). This will be discussed in chapter 3, where we relax the no agency costs assumption.

[Place Figure 3 about here]

A key assumption of our paper is that the initial endowment from the firm can only be placed into the *Regbond*, otherwise it will only be held by the firm and will not earn any interest payment. The implication is that the initial endowment will not be considered as part of the investment budget. However, if the firm gets convicted, the default of

Regbonds is borne directly by the firm and is thus considered when calculating the returns to the firm. Furthermore, as the *Regbonds* results in a higher loss to the firm in a conviction event, this implies that the firm's internalization variable will increase from μ to $(\mu + x)$. Likewise, the interest payment from the regulators (and/or external stakeholders) will come from a pool of reserves that are usually set aside for financial loss events and will not be part of the deterrence investment budget. For simplicity of analysis, we further assume that the externalized financial losses are borne solely by regulators. The reason for these assumptions is that our focus is on how the firm behavior changes in light of a *Regbond* setting. It is straightforward to see that our key findings do not change when these assumptions are relaxed.

Our model assumes that the regulator should attempt to reduce gray project investments, even though these investment projects have not yet been determined to be illegal. Therefore, it might not be reasonable for regulators to implement this in the real-world. However, the purpose of our models is to illustrate the benefits that could be reaped if regulators were to discourage gray project investments. In essence, the insights generated from our models provide regulators with a justification to discourage investments in activities that might potentially be illegal. Furthermore, the external costs arising from gray project investments are significant as documented by real-world evidence. [7] Therefore, we propose that there exists sufficient justification for regulators to discourage investments in gray projects. Nevertheless, we agree that the regulators need to weigh the benefits, costs and reasonableness of their policies before any real-world implementation. Our model provides policymakers with a tool to better understand the impacts of their policies as well as the hidden costs of gray project investments.

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[7] As gray project investments are a relatively new concept, we proxy for these costs by looking at the fines and penalties imposed on activities that were only deemed illegal after these activities had been running for years. For example, the A.I.G. Finite Reinsurance Scandal in 2006 had been running for close to two decades before being deemed as an illegal activity by regulators. They were ordered to pay back US$1.5 billion to victims of their gray project investment, "A.I.G. Apologizes and Agrees to $1.64 Billion Settlement", *The New York Times*, 02/10/2006. Another example would be data privacy concerns, where regulators increasingly understand the importance of data protection. The European Union (EU) enacted the General Data Protection Regulation (GDPR) and seek to penalize companies in violation of the GDPR. The largest fine to date is 183 million pounds imposed on British Airways, "BA hit by biggest GDPR fine to date", *Financial Times*, 07/09/2019. These numbers provide a proxy for the costs of gray project investments.

Our model also assumes that the initial endowment can only be invested in *Regbonds* and nothing else. Admittedly this is a strong assumption, and we required this assumption to keep our analysis mathematically tractable. However, even if we were to weaken this assumption, where firms can now choose to invest their initial endowment in other financial instruments, our main results do not change. Weakening our assumption implies that there exists an additional opportunity cost if the firm chooses to invest in *Regbonds*. The result would be the coupon rate required for *Regbonds* to be feasible will now be more expensive as the firm needs to incorporate the opportunity costs of not investing in alternative financial instruments. This does not affect the signaling mechanism of *Regbonds* that underlies our main results.

Furthermore, our model assumes that the regulators are unable to lay claim on any of the endowment after misconduct was detected, unless the endowment was placed in a *Regbond*. Admittedly this may be a strong assumption, but we propose that this ties in with anecdotal evidence. [8] We document that despite the poor decision-making by managers, these executives managed to exit the firm with a good amount of compensation. Therefore, we propose that in the real-world, the threat of regulators laying their claim on the endowment of the firm, ex-post detection of misconduct, is not as high as we hope it to be. Therefore, we propose that this assumption is generally in line with real-world expectations – unless the firm places the endowment in a Regbond, it will be relatively harder for regulators to lay claim on it. This also brings us to our next point where we discuss the need for a firm to ex-ante post a *Regbond*, rather than having regulator impose ex-post fines on offenders. Our models do not assume limited liability, but the notion that the firms end up being the ones on the hook for hefty fines while the key decision-makers (i.e. the managers) tend to walk away with large sums of endowment. In this case, there is an implicit assumption that there is limited liability for decision-makers. Therefore, even if the amount of financial penalty and the posted *Regbond* might be the same, the impact is vastly different. When we have the traditional ex-post financial penalty, R (that

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[8] For example, top bankers whose decisions triggered the subprime mortgage crisis in 2008, managed to walk away from the disaster with millions of dollars, "These Disgraced Wall Street Kingpins Are Living Quite Nicely 5 Years After Crisis", *The Huffington Post*, 09/10/2013. In a similar note, the top executives that triggered the collapse of Lehman Brothers Holdings Inc. and Bear Stearns Cos. cashed out nearly US$2.5 billion from their firm, "Lehman, Bear Executives Cashed Out Big", *The Wall Street Journal*, 11/22/2009.

we assumed to be fixed in our models), the firms are the ones paying up. However, in the case of an ex-ante posting of *Regbonds*, managers will be forced to bear a portion of the costs. Therefore, an ex-ante posting of *Regbonds* help to ensure managers internalize a greater portion of their decision-making relative to an ex-post financial penalty, and this is a key distinction between the two seemingly similar strategies.

4.2 *Regbonds*: Compulsory Setting

In a compulsory setting where the posting of *Regbond* is mandated by regulators, all firms will need to put up a certain portion of their endowment into the *Regbonds*. We define the following:

$$x = \frac{X}{R},$$

$$x \leq 1 - \mu.$$

This yields Figure 4 that plots the firm's returns under a mandated posting of *Regbonds* setting.

[Place Figure 4 about here]

Specifically, X is the fixed dollar amount of *Regbonds* that must be posted by all firms as mandated by regulators, x is simply the proportion of X to the financial loss, and r_{reg} is the interest payment to the firms for posting *Regbonds*. We further require that the total amount of mandated *Regbonds* must not exceed the amount of externalize financial loss. This is because it will not be equitable for firms to put aside an amount that will lead to an over-internalization of financial losses arising from their decisions.

The implicit assumption of our model is that the interest payment will be paid right before the announcement of the financial loss event. This implies that the posting firms will always earn a return, r_{reg}, on their posted *Regbonds*. Given that the regulators have

mandated for the posting of *Regbonds* by firms. This yields the following optimization problem by firms:[9]

$$\max_{z} \quad E(Return)$$

$$s.t. \quad b = y + z.$$

Solving the optimization problem yields the following optimal allocation of gray project investments by firms.

$$\tilde{y}_{reg} \quad = \quad b - \tilde{z}_{reg}$$

$$\tilde{z}_{reg} \quad = \quad \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot (\mu + x) \cdot R}\right]^{\frac{1}{\alpha-1}}.$$

Proposition 5: The amount of gray project investments will decrease when *Regbonds* are mandated and the following relationship holds:

$$\tilde{z} \leq \tilde{z}_{reg} < \tilde{z}_{ext}$$

Proposition 6: The amount of gray project investments under mandate will tend towards the optimal gray project investments as the posted *Regbonds* amount increases and the following relationship holds:

$$\lim_{x \to (1-\mu)} \left(\tilde{z}_{reg}\right) = \tilde{z}$$

Our result shows that when *Regbonds* are posted by firms, the amount of gray project investments decreases and tends towards the optimal. This ties in with our expectation as the firm now internalizes a greater portion of the financial loss and brings down the amount of gray project investments. *Regbonds* help firms to internalize the external costs of their decisions. This brings the gray project investments towards optimal and reduces

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[9] Based on Figure 4, $E(Return) = gv(z)\left[r_{reg} + \frac{yr_{g=0} + zr_{g>0} - (\mu+x)R}{b}\right] + \left(1 - gv(z)\right)\left[r_{reg} + \frac{yr_{g=0} + zr_{g>0}}{b}\right]$

the overinvestments in gray projects by firms. It is theoretically feasible for regulators to mandate an *x* amount that will have the firm fully internalize the cost of their actions.

Next, we consider the conditions necessary for regulators to mandate for all firms to post *Regbonds*. The regulators can mandate for all firms to post *Regbonds* either ex-ante or ex-post the firm's allocation of investment budget. Both strategies are equally likely and will yield different conditions. We first consider the ex-post setting where regulators mandate for the posting of *Regbonds* after firms have decided on the allocation of their investment budget. This yields Figure 5 that plots the costs to regulators under a compulsory and ex-post setting.

[Place Figure 5 about here]

Proposition 7: We show that the following condition must hold for the mandate of *Regbonds* to be feasible to regulators under ex-post setting:

$$r_{reg} < g \cdot v(\tilde{z}_{ext})$$

(Proof E)

Our result implies that regulators will only consider the interest payment on *Regbonds*, probability of the gray investment project turning out to be illegal and the conviction probability of the firm. The actual amount of financial loss, the internalization variable and other factors do not affect whether or not the regulator will choose to mandate the posting of *Regbonds* under the ex-post setting.

However, in the ex-ante setting where firms will make a conscious adjustment to the allocation of their investment budget in response to a mandate of *Regbonds*, we yield Figure 6 that plots the costs to regulators under a compulsory and ex-ante setting.

[Place Figure 6 about here]

Proposition 8: We show that the following condition must hold for the mandate of *Regbonds* to be feasible to regulators under ex-ante setting:

$$X < \frac{g \cdot (1 - \mu) \cdot R \cdot [v(\tilde{z}_{ext}) - v(\tilde{z}_{reg})]}{r_{reg} - g \cdot v(\tilde{z}_{reg})}$$

(Proof F)

Our result implies that in an ex-ante setting, in addition to the factors considered under ex-post setting, regulators now need to also consider the actual amount of financial loss, the internalization variable and more importantly the amount of mandated *Regbonds* to be posted. This means that there exists an upper limit on X, above which will make the posting of *Regbonds* more costly than if the regulators were to internalize the full external costs of decisions made by the firms.

We propose the key difference between the ex-ante and ex-post setting is that in the ex-ante setting, the feasibility of the posting of *Regbonds* is affected by the amount of *Regbonds* to be posted. However, in the ex-post setting, the feasibility does not depend on the amount of *Regbonds* to be posted.

Next, we assume the ex-post setting holds to better understand a potential limitation of mandated *Regbonds*. We consider a two-firm setting, whose result can be easily extrapolated to a multi-firm setting. Similar to section 3.3, there exists a good firm and a bad firm where:

$$\mu_{good} > \mu_{bad},$$

$$\tilde{z}_{bad} > \tilde{z}_{good}.$$

Under a compulsory posting of *Regbonds*, we assume the amount that will be posted will be the same across all firms in the ecosystem.[10] Hence, both the good and bad firms will be mandated to post the same amount of *Regbonds*. We propose that the amount of

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[10] It is possible for regulators to mandate some firms to have a greater posting amount than other firms, but this is not optimal under an asymmetric information setting (i.e. our assumed setting). Therefore, as proposed in section 3.3, the optimal mandate under an asymmetric information setting will be to require all firms to post the same amount of *Regbonds*.

Regbonds to be posted can take the following domain, where: (1) $x < 1 - \mu_{good}$, (2) $x = 1 - \mu_{good}$, (3) $x = 1 - \mu_{bad}$, and (4) $x > 1 - \mu_{bad}$.

We then analyze the impact of having a mandated posting of *Regbonds* on firms for each of the domain. Under the first domain, the mandated x posted amount will not allow both good and bad firms to fully internalize the external costs of their decisions. Under the second domain, the mandated x posted amount will allow the good firm to fully internalize the external costs of her decision while the bad firm will continue to overinvest in gray projects. Under the third domain, the bad firm will now fully internalize the external costs of her decision but the good firm is now overdeterred and will underinvest in gray projects and this is suboptimal. Finally, under the fourth domain, both the good and bad firms are overdeterred and the total gray project investments in the ecosystem will be less than optimal.

> Proposition 9: In a multi-firm ecosystem, a mandated *Regbond* system will help firms internalize the external costs of their decisions. However, the internalization of external costs will not be perfect for all firms – some firms will continue to overinvest in gray projects while others might even underinvest in gray projects, both scenarios are suboptimal behavior.

Therefore, our results show that having a mandated *Regbond* system will be able to mitigate the problem outlined in section 3.2. *Regbonds* will help firms internalize the external costs of their decisions. However, having a fixed mandated amount of *Regbonds* across different firms will not allow for a perfect internalization of external costs for all firms. Some might propose to mandate a different amount of *Regbonds* for different firms (i.e. higher and lower amount of *Regbonds* for bad and good firms, respectively). This is indeed feasible under a symmetric information setting. However, in reality, where asymmetric information is the norm, it will be difficult for regulators to ex-ante differentiate between the good firm and the bad firm. Therefore, the optimal decision function from the regulators will be to mandate a fixed amount of *Regbonds* for all firms under an asymmetric information setting. This leads to the imperfect internalization of external costs for all firms.

The key problem here is the information asymmetric setting that makes it difficult for regulators to identify the good firm and the bad firm. We seek to solve this issue in the following section.

4.3.1 *Regbonds*: Voluntary Setting

In the previous section, we show that *Regbonds* under a compulsory setting will be able to reduce the total gray project investments within the ecosystem. However, this does not solve the problems associated with asymmetric information that prevents a perfect internalization of external costs for all firms. Therefore, in this section, we propose having *Regbonds* under a voluntary setting (where posting of *Regbonds* is a non-reversible undertaking) will be able to act as a signal that regulators can pick up and identify the good firms and bad firms.

First, we begin with the model laid out in section 3.3 where there exists two firms, one good and one bad and they are identical apart from their conviction probability density function and internalization variable. The differences are given as follows:

$$z^*_{0,good} < z^*_{0,bad},$$

$$\mu_{good} > \mu_{bad}.$$

Given the above relationships are true and that all other parameters hold true, the trivial result is that the following holds true as well:

$$z^*_{good} < z^*_{bad},$$

$$\tilde{z}_{good} < \tilde{z}_{bad}.$$

Recall that the conviction probability density function for both the good and bad firm is defined as follows:

$$v(\tilde{z}_i) = \begin{cases} \left(\dfrac{\tilde{z}_i}{z^*_i}\right)^\alpha & , \quad \tilde{z}_i < z^*_i \text{ and } \alpha > 1 \\ 1 & , \quad \tilde{z}_i \geq z^*_i \end{cases}, \qquad where\ i = bad, good.$$

Proposition 10: We show that when the following is true:

$$z^*_{0,good} < z^*_{0,bad}$$

$$\mu_{good} > \mu_{bad}$$

Then the following must hold true as well:

$$v(\tilde{z}_{good}) < v(\tilde{z}_{bad})$$

(Proof G)

Next, we conduct a marginal benefits analysis to determine the payoffs of *Regbonds* from the firm's perspective. In a voluntary *Regbond* system, where the coupon payment has already been determined by regulators, the ex-ante setting takes hold as firms respond to the feasibility of posting *Regbonds* and make the necessary adjustments in their allocation of the investment budget. In Figure 7, we plot the net payoff to firm under such a setting.

[Place Figure 7 about here]

Proposition 11: A firm will choose to post *Regbonds* if and only if the interest on the *Regbonds* exceeds a threshold where the following relationship holds:

$$r_{reg} > \frac{\left(\left((z^*) \cdot (r_{g>0} - r_{g=0})\right)^{\frac{\alpha}{\alpha-1}}\right) \cdot \left((\mu + x)^{\frac{1}{1-\alpha}} - (\mu)^{\frac{1}{1-\alpha}}\right) \cdot \left(\frac{1}{\alpha} - 1\right)}{X \cdot \left((\alpha g R)^{\frac{1}{\alpha-1}}\right)}$$

$$= q$$

(Proof H)

We document that the result in Proposition 11 is in line with our expectation. For example, when the financial penalty, *"R"*, or the legality parameter, *"g"*, increases, the expected cost of conviction to the firm also increases. This makes the firm less likely to invest more in gray projects and will thus be more likely to fulfil the condition in Proposition 11 and post *Regbonds*. A firm will compare the expected payoffs with and without *Regbonds* and we show that if the condition in Proposition 11 holds, it implies that the expected payoff with *Regbonds* exceed that without. Consequently, a firm will choose to post *Regbonds*

voluntarily. Assuming that we now have an active regulator under an asymmetric information setting and an ex-ante equal allocation of the deterrence budget across both good and bad firms.

Proposition 12: We further show that the following is true:

$$\frac{\partial q}{\partial z^*} > 0$$

$$\frac{\partial q}{\partial \mu} < 0$$

(Proof I)

Proposition 13: Assuming all else is equal between the good and bad firm apart from their conviction probability density function and internalization variable, where:

$$z_{0,good}^* < z_{0,bad}^*$$

$$\mu_{good} > \mu_{bad}$$

Coupled together with the results in Proposition 12, it is easy to see that the following is true:

$$q_{good} < q_{bad}$$

Assuming that the predetermined interest rate on the *Regbond* falls between that of q of the good and bad firm, where:

$$q_{good} < r_{reg} < q_{bad}.$$

Based on the results in Proposition 11, the implication is that good firms will rationally choose to post *Regbonds* while bad firms will choose not to do so. Therefore, the posting of *Regbonds* will help the good firm internalize the external costs of their decisions while bad firms will continue to externalize the costs of their decisions if no further shocks are made to the ecosystem.

Given our prior assumption of an active regulator, where the posting of <u>*Regbonds*</u> is an event that can be publicly observed, regulators will receive information on the underlying

nature of the firm. Based on this information, regulators no longer need to allocate their deterrence budget equally between the good and bad firms but rather, the regulator can allocate a greater portion of their deterrence budget towards the bad firm, where:

$$m_{good} < m_{bad}.$$

This adjustment to the allocation of the deterrence budget concentrates a greater portion of the deterrence budget towards the bad firms. This leads to a greater percentage reduction in the bad firm's z^*. Following the similar analysis above, the bad firm's q now decreases and the bad firm's resulting q will now either be (1) below r_{reg} or (2) continue to remain above r_{reg}.

Under the first scenario, the bad firm, after receiving a greater portion of the deterrence budget, will now choose to post *Regbonds* and internalize the external costs of their decisions. Under the second scenario, although the bad firm will still choose not to post *Regbonds*, but the reduction in the firm's z^* means that the bad firm's gray project investment is also reduced and tends closer towards the optimal gray project investment. We see that the result of scenario 1 outweighs that of scenario 2 while the results of both scenarios outweigh the setting without voluntary *Regbonds*.

4.3.2 *Regbonds*: Voluntary Setting (*N* firms)

In the previous section, we propose that *Regbonds* can act as a signaling mechanism towards active regulators and help to reduce the gray project investments under a two-firm setting. In this section, we qualitatively extend our results to an ecosystem with *N* firms where firms are ordered based on their q.

When the system of voluntary *Regbonds* is set-up, we see that a portion of the firms will choose to post *Regbonds* and internalize the external costs of their decisions. The regulators receive signal from the ecosystem and is now able to accurately target their deterrence budget towards the bad firms (i.e. firms that did not post *Regbonds*). This reduces the z^* of this group of bad firms and also reduces their q. Within this group of bad firms, some of their q will now fall lower than r_{reg} and will choose to post *Regbonds*.

We term this as the snowballing effect where bad firms will start to post *Regbonds* after good firms post *Regbonds*. The equilibrium will either be (1) all firms in the ecosystem posting *Regbonds* or (2) only a portion of *N* firms choosing to post *Regbonds*.

Under the first scenario, all firms will have better internalized the external costs of their decisions and the aggregate gray project investments in the ecosystem will decrease and tend towards optimal. Under the second scenario, the firms that have posted *Regbonds* will have better internalized the external costs of their decisions and reduce their gray project investments. For firms that did not post *Regbonds*, regulators will observe that the underlying nature of these firms are bad. Regulators will then choose to allocate a greater portion of their deterrence budget towards these bad firms and this increases their conviction probability at all levels of gray project investments. This implies that the aggregate gray project investments of these bad firms will have decreased as well. Taken together, the aggregate gray project investments of both good and bad firms will have decreased as well and tend towards the optimal under the second scenario.

Therefore, our result calls for the set-up of a *Regbond* system where it will help firms internalize the external costs of their decisions and reduce the aggregate gray project investments in the ecosystem.

In addition, we note that if we relax the assumption and allow managers to preempt future actions, there exists a feasible condition where bad firms will choose to also post *Regbonds* so as to avoid regulatory scrutiny by regulators (i.e. copy a good firm). We propose that this is feasible, but by posting *Regbonds* imply that the bad firm would have internalized the cost of their decision-making, that they would otherwise not have without the *Regbonds*. That said, we agree that this will make for an interesting follow-up paper as well.

Finally, in a bid for a more holistic analysis, we provide a discussion on the potential negative side-effects of *Regbonds*. Specifically, posting *Regbonds* would require a significant amount of capital commitment from the firms. This might be a potential barrier to entry and result in a reduction in market entry. As a result, competition is diminished and will likely result in higher prices for consumers. Furthermore, an asymmetric effect will take hold, where individuals from less wealthy families will find it

harder to start a business relative to those from more wealthy families. Therefore, we would like to highlight that no mechanism is perfect, and that it is of critical importance for regulators to balance the benefit and cost of *Regbonds*. A potential method for regulators to better manage the aforementioned cost of *Regbonds* would be to allow only large corporations to post *Regbonds* – and to exempt small-and-medium enterprises (SMEs) from posting *Regbonds*. Taking this a step further, regulators might even only require globally systemically important financial institutions (G-SIFIs) and/or systemically important financial institutions (SIFIs) to post *Regbonds*. Such a methodology is two-fold. First, given the size and importance of these large organizations, it ensures that the signaling and regulatory effect of *Regbonds* are maximized. Second, exempting SMEs from posting *Regbonds* ensure that the asymmetric effect of *Regbonds* on less wealthy individuals (and/or smaller companies) are mitigated. Taken together, we show that *Regbonds*, similar to other mechanisms, is not a perfect instrument. Regulators should only utilize *Regbonds* after a good amount of careful planning and consideration of the associated costs and benefits.

5. Empirical Analyses

Our earlier sections provide theoretical modelling and discussions. The purpose of this section is to provide empirical support for the propositions that we derived in this thesis. However, due to the nature of gray project investments, as well as the novelty of *Regbonds* (i.e. it has not been issued in the real-world), it is difficult to conduct robust analysis on all our Propositions. However, in spite of limited availability of data, I derive useful proxies and seek to show specific arguments to hold true. Specifically, we test the optimal solution for gray project investments in the presence of an active regulator (as given in section 3.3). The key idea is that when regulators increase their deterrence investment m, it results in a reduction of z^* as well as the optimal gray project investments $\tilde{z}$. We test this argument with a country panel dataset.

Data Description: Our data is extracted primarily from the "World Justice Project (WJP) Rule of Law Index". The database captures different measures for the Rule of Law within a country, across 126 countries from 2012 to 2019. These measures include

AbsenceCorruption, *RegulatoryEnforcement*, *OrderSecurity*, *GovernmentPowerConstraint*, *OpenGovernment*, *FundamentalRight*, *CivilJustice*, and *CriminalJustice*. As companies do not usually publicly announce the level of investments they have in gray projects, we propose that a reasonable proxy for $\tilde{z}$ within the country will be the level of corruption within the country. The underlying notion is because firms seek to reduce their conviction probability by means of lobbying or at times, bribing of politicians, when firms engage in higher levels of $\tilde{z}$. On the contrary, the need to bribe politicians diminish significantly when firms are not engaging in gray project investments (i.e. their investments are all perfectly legal). Therefore, we propose that the level of corruption within a country (*AbsenceCorruption*) can be a reasonable proxy for $\tilde{z}$.

As for the proxy of deterrence investments m, we have three main groups of proxies. The first group is the more direct measure of regulatory and enforcement, and we proxy this with *RegulatoryEnforcement*. The rationale is that when the regulators invest more in deterrence investments, we expect the regulatory and enforcement environment in the country to be stronger and bring about a higher *RegulatoryEnforcement* score. The second and third groups are more indirect measures of deterrence investments. The second group focuses on "Government Security Investment", and is proxied by *OrderSecurity*, *GovernmentPowerConstraint*, and *OpenGovernment*. The rationale here is that when the government places a greater focus on being open and limiting their power, while at the same time ensuring that the country is both orderly and safe, it is likely that the government also places a high emphasis on deterrence investments in deterring gray projects. Finally, the third group focuses on "Justice Rights Investment", and is proxied by *FundamentalRight*, *CivilJustice*, and *CriminalJustice*. The reason for these measures is that when the justice system in the country is just and that individuals possess fundamental rights, it is likely that the government views such justice mechanisms as important and are thus more likely to invest heavily in deterring gray projects. Therefore, *RegulatoryEnforcement* is our direct measure of m, whereas the remaining measures (i.e., *OrderSecurity*, *GovernmentPowerConstraint*, *OpenGovernment*, *FundamentalRight*, *CivilJustice*, and *CriminalJustice*) are considered indirect measures of m.

Table 1 shows the summary statistics of the data. Detailed variable descriptions are in Table A1. Panel A summarizes the data of our main sample on the country × year level,

with a total of 857 observations from 2012 to 2019. Panel B summarizes the unique number of observations in our dataset.

AbsenceCorruption is score for the country in the year observation, rescaled to an index ranging from 0 to 1. The mean is 0.531, this means that the average score in our sample is above the midpoint score of 0.500. For brevity, the remaining variables are our key independent variables of interest, and we document that the average score for these variables tend to rank above the midpoint score of 0.500, except for *CriminalJustice* that has an average score of 0.498 (this is still near the midpoint score).

[Place Table 1 about here]

We apply the following linear model with both country- and year-fixed effects to mitigate concerns about omitted variables and control for both time-variant and time-invariant factors:

$$AbsenceCorruption_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta(Key\ independent\ variable)_{i,t} + \varepsilon_{it} - (1)$$

where α_0, α_i, $and\ \alpha_t$ represent the constant, country i fixed-effect and year t fixed-effect, respectively. The normally distributed error term is denoted by ε_{it}. The dependent variable is the *AbsenceCorruption*, and this proxy for the level of $\tilde{z}$ in our dataset. Our key independent variables are the 3 different groups of measures that proxy for m. We are primarily interested in estimating the parameter β as it captures the influence of a change in m on $\tilde{z}$.. We also cluster our standard errors by country.

We first focus on the direct measure of m, given by *RegulatoryEnforcement*, within the country. Results are reported in Table 2. In column (1), we do not control for fixed-effects and the estimated β coefficient for *ConstructionPermit* is 0.710 and is significant at the 1% level. This means as the strength of the regulatory and enforcement environment becomes stronger and increases the score of *RegulatoryEnforcement* by 1 point, this leads to an increase in *AbsenceCorruption* of 0.710 point, and this corresponds with a reduction in corruption level of the country. Furthermore, to account for time-variant effects, we control for year-fixed effects in column (2), and continue to document robust results where the coefficient is 0.769 and is significant at the 1% level. Finally, we also control for country-fixed effects, to account for time-invariant effects, in column (3) and results

continue to remain robust with a coefficient of 0.405 and is significant at the 1% level. Taken together, our results show that an improvement in the regulatory and enforcement environment of a country is positively associated with a reduction in the corruption level of the country.

[Place Table 2 about here]

Next, we focus on the group of measures that look at the level of government security investments within the country: *OrderSecurity*, *GovernmentPowerConstraint*, and *OpenGovernment*, results are reported in Table 3. In column (1), we do not control for fixed-effects and the estimated β coefficient for *OrderSecurity* is 0.232 and is significant at the 1% level. This means that as the level of order and security in the country increases in score by 1 point, this leads to an increase in *AbsenceCorruption* of 0.232 point, and this corresponds with a reduction in corruption level of the country. In columns (4) and (7), we repeat the similar analyses with *GovernmentPowerConstraint* and *OpenGovernment* as our key independent variable of interest, and we document that the estimated coefficient is 0.513 and 0.264, both with a significance of 1%. Furthermore, to account for time-variant effects, we control for year-fixed effects in columns (2), (5), and (8) and continue to document robust results. Finally, we also control for country-fixed effects, to account for time-invariant effects, in columns (3), (6), and (9) and results continue to remain robust. Taken together, our results show that an improvement in the level of government security environment in a country is positively associated with a reduction in corruption level of the country.

[Place Table 3 about here]

Third, we focus on the group of measures that look at the level of justice rights investments within the country: *FundamentalRight*, *CivilJustice*, and *CriminalJustice*, results are reported in Table 4. In column (1), we do not control for fixed-effects and the estimated β coefficient for *FundamentalRight* is 0.391 and is significant at the 1% level. This means that as the ease of conducting cross border trades increases in score by 1 point, this leads to an increase in *AbsenceCorruption* of 0.391 point, and this corresponds with a reduction in corruption level of the country. In columns (4) and (7), we repeat the similar analyses with *CivilJustice* and *CriminalJustice* as our key independent variable of

interest, and we document that the estimated coefficient is 0.585 and 0.549, both with a significance of 1%. Furthermore, to account for time-variant effects, we control for year-fixed effects in columns (2), (5), and (8) and continue to document robust results. Finally, we also control for country-fixed effects, to account for time-invariant effects, in columns (3), (6), and (9) and results continue to remain robust. Taken together, our results show that an improvement in the justice rights ecosystem in a country is positively associated with a reduction in corruption level of the country.

[Place Table 4 about here]

We conduct two additional sets of robustness tests. The first set of robustness test, we further control for the income level of the country in our regressions, to account for potential explanatory power arising from the income level of the country on the corruption level of the country. We repeat the analyses in Tables 2, 3, and 4 with the control for income level and results are documented in Tables A2, A3, and A4, respectively, and we continue to document robust results. In the second set of robustness test, we replace country fixed effects by region fixed-effects. We also cluster our standard errors by region, this is to account for specific time-invariant fixed effects across regions that are not captured by the country fixed-effects. We repeat the analyses in Tables 2, 3, and 4 with this robustness test and results are documented in Tables A5, A6 and A7, respectively, and our results continue to remain robust to these checks.

Taken together, our results show that when the direct measures (*RegulatoryEnforcement*) and indirect measures (*OrderSecurity*, *GovernmentPowerConstraint*, *OpenGovernment*, *FundamentalRight*, *CivilJustice*, and *CriminalJustice*) of deterrence investments improves, this results in a reduction in corruption level in the country. Given that our various direct and indirect measures is a good proxy for deterrence investments m, and that *AbsenceCorruption* is a good proxy for $\tilde{z}$, our results lend credence to the various propositions derived from our model, as well as the validity of the model.

6. Conclusion

In sum, our paper extends on the basic model proposed in chapter 1, and shows that there exists overinvestments of gray projects at the aggregate level. Furthermore, information asymmetry results in an inefficient allocation of deterrence investments by regulators. In response, this paper presents a novel solution, the *Regbonds*. The *Regbonds* function like a bond, but will default only in the event of regulatory conviction. Otherwise, it will pay back the principal and coupon payment to bondholders. Furthermore, unlike traditional bonds, *Regbonds* will not be used to finance firm's capital investments but will be set aside in escrow. This paper then shows that under the compulsory setting, *Regbonds* reduce the aggregate gray project investments. However, this setting does not allow for a perfect internalization of external costs across all firms and still lead to a suboptimal behavior. We then show that this issue is solved under a voluntary setting, as regulators can more efficiently allocate deterrence investments towards bad firms. Regulators can do this as *Regbonds* now act as a signaling mechanism and mitigates the information asymmetry problem. In our analysis, we assumed that incentives between shareholders and managers are perfectly aligned. In chapter 3, we relax this assumption and analyze the impact of *Regbonds* on gray project investments by firms and how it can help to mitigate the agency problems.

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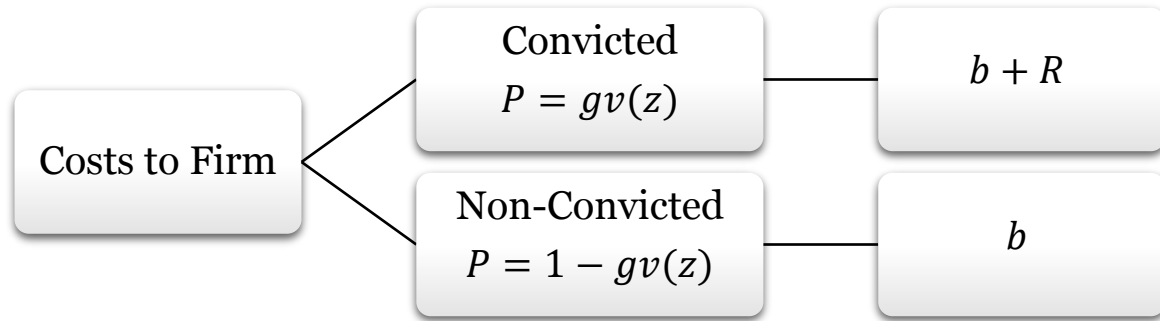
FIGURE 1. COSTS TO FIRM (UNDERTAKING GRAY PROJECT INVESTMENTS)

Returns to Firm

Convicted
$P = gv(z)$

$$\frac{yr_{g=0} + zr_{g>0} - R}{b}$$

Non-Convicted
$P = 1 - gv(z)$

$$\frac{yr_{g=0} + zr_{g>0}}{b}$$
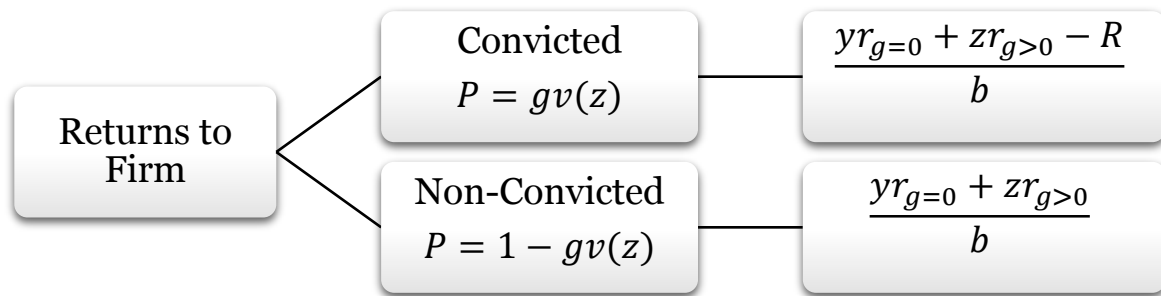
FIGURE 2. RETURNS TO FIRM (UNDERTAKING GRAY PROJECT INVESTMENTS)

$t = 0$	$t = 1 - \Delta t$	$t = 1$
Firm posts *Regbonds* by putting up cash (cash is held in escrow)	Firm receives coupon payment	1. If the firm is not convicted, firm gets back the cash held in escrow 2. If the firm is convicted, the cash held in escrow is used to pay of the financial losses
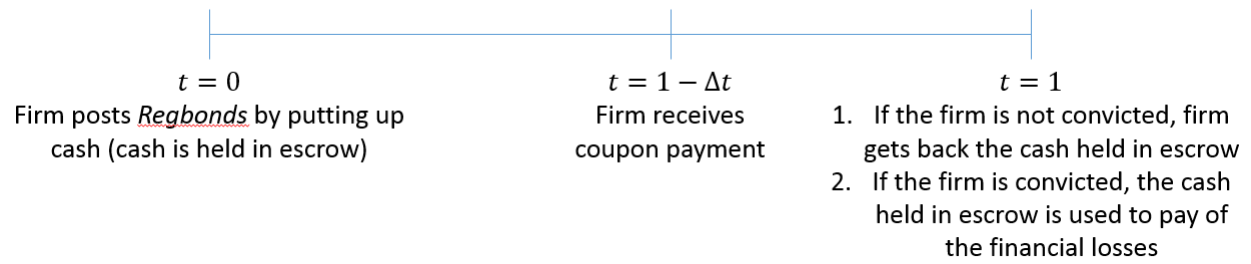
FIGURE 3. Timeline of posting of *Regbonds* by firms

$$\text{Returns to Firm} \begin{cases} \text{Convicted} \\ P = gv(z) \end{cases} \quad r_{reg} + \dfrac{yr_{g=0} + zr_{g>0} - (\mu + x)R}{b}$$

$$\begin{cases} \text{Non-Convicted} \\ P = 1 - gv(z) \end{cases} \quad r_{reg} + \dfrac{yr_{g=0} + zr_{g>0}}{b}$$
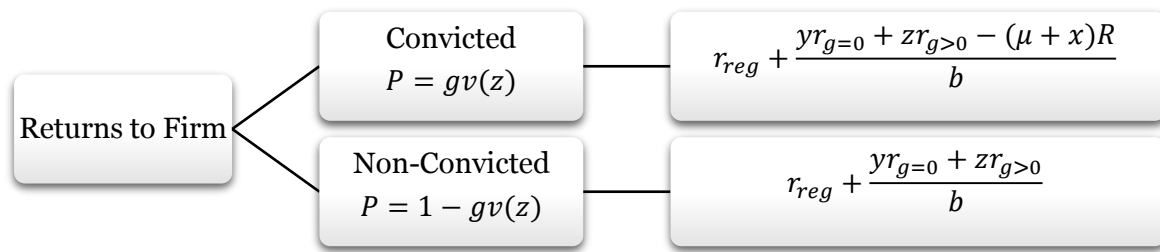
FIGURE 4. *REGBONDS* ARE MANDATED: RETURNS TO FIRM (UNDERTAKING GRAY PROJECT INVESTMENTS)
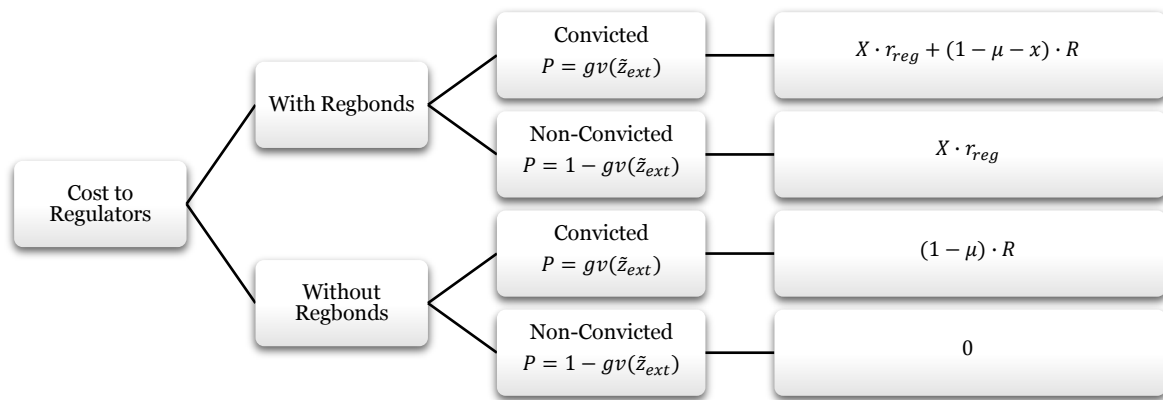
FIGURE 5. *REGBONDS*: COST TO REGULATORS (EX-POST)
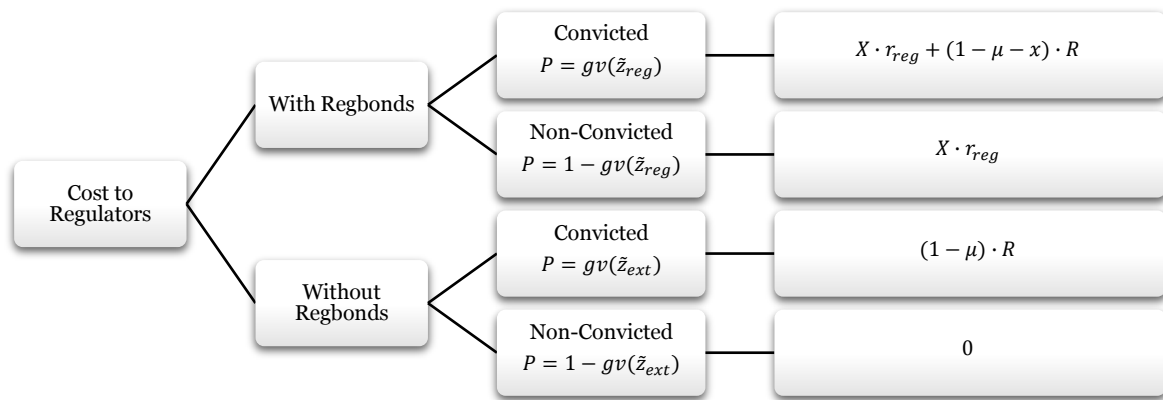
FIGURE 6. *REGBONDS*: COST TO REGULATORS (EX-ANTE)
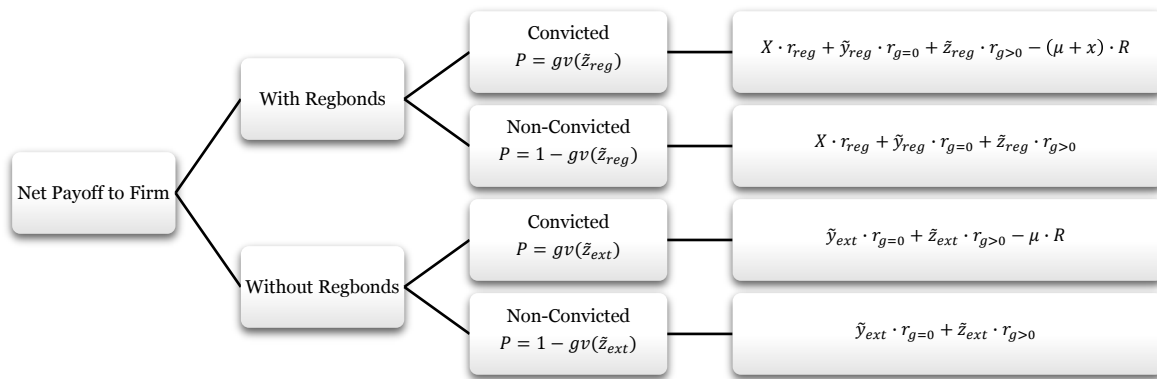
FIGURE 7. *REGBONDS*: NET PAYOFF TO FIRM

Table 1
Summary Statistics

Panel A: Country x Year

Variables	Observations	Mean	S.D.	Min	Max
AbsenceCorruption	857	0.531	0.194	0	1
RegulatoryEnforcement	857	0.540	0.149	0	1
OrderSecurity	857	0.719	0.127	0	1
GovernmentPowerConstraint	857	0.570	0.163	0	1
OpenGovernment	857	0.526	0.153	0	1
FundamentalRight	857	0.596	0.154	0	1
CivilJustice	857	0.552	0.134	0	1
CriminalJustice	857	0.498	0.162	0	1

Panel B: Unique no. of observations

Variables	Observations
Unique no. of countries	126
Unique no. of years	8
Unique no. of regions	6
Unique no. of income groups	4

Notes: This table describes the summary statistics of our sample. Panel A provides the summary statistics at the country x year level for our panel database. Panel B describes that the data are restricted to 126 unique countries of 4 different income groups across 6 regions between 2012 and 2019. See Table A1 for detailed variable definitions.

Table 2
Absence of Corruption and Regulatory Enforcement Investment

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption
RegulatoryEnforcement	0.710***	0.769***	0.405***
	(0.0693)	(0.0660)	(0.100)
Constant	0.145***	0.119***	0.316***
	(0.0371)	(0.0360)	(0.0538)
Observations	857	857	857
YearFE	NO	YES	YES
CountryFE	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the *RegulatoryEnforcement*, and this is a direct measure for *m*, *AbsenceCorruption* is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Column (1) do not include any fixed-effects, column (2) include year fixed-effects, and column (3) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3
Absence of Corruption and Government Security Investment Measures

	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
Dependent Variable									
OrderSecurity	0.232*** (0.0576)	0.248*** (0.0597)	0.147** (0.0660)						
GovernmentPowerConstraint				0.513*** (0.0570)	0.519*** (0.0573)	0.404*** (0.0668)			
OpenGovernment							0.264*** (0.0422)	0.339*** (0.0443)	0.234*** (0.0507)
Constant	0.356*** (0.0396)	0.351*** (0.0401)	0.429*** (0.0468)	0.235*** (0.0328)	0.235*** (0.0329)	0.303*** (0.0375)	0.387*** (0.0236)	0.356*** (0.0242)	0.413*** (0.0255)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the *OrderSecurity*, columns (4)-(6) report results for the *GovernmentPowerConstraint*, and columns (7)-(9) report results for the *OpenGovernment*. These three are measures for the level of government security investment, and are indirect measures for m, *AbsenceCorruption* is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 4
Absence of Corruption and Justice Rights Investment Measures

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
FundamentalRight	0.391***	0.436***	0.272***						
	(0.0758)	(0.0747)	(0.0859)						
CivilJustice				0.585***	0.633***	0.236***			
				(0.0474)	(0.0511)	(0.0669)			
CriminalJustice							0.549***	0.652***	0.272***
							(0.0537)	(0.0531)	(0.0710)
Constant	0.292***	0.259***	0.366***	0.203***	0.178***	0.402***	0.255***	0.186***	0.389***
	(0.0436)	(0.0450)	(0.0520)	(0.0250)	(0.0262)	(0.0364)	(0.0247)	(0.0271)	(0.0369)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the *FundamentalRight*, columns (4)-(6) report results for the *CivilJustice*, and columns (7)-(9) report results for the *CriminalJustice*. These three are measures for the level of justice rights investment, and are indirect measures for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix

Table AI
Variable Definitions and Constructions

Variable	Description
AbsenceCorruption	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *AbsenceCorruption* is an index that ranges from 0 (highly corrupt) to 1 (no corruption). The index is computed by accounting for various aspects of corruption within the country.
RegulatoryEnforcement	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *RegulatoryEnforcement* is an index that ranges from 0 (weak regulatory enforcement) to 1 (strong regulatory enforcement). The index is computed by accounting for various aspects of regulatory and enforcements in the country.
OrderSecurity	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *OrderSecurity* is an index that ranges from 0 (weak order and security) to 1 (strong order and security). The index is computed by accounting for various aspects of order and security within the country.
GovernmentPowerConstraint	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *GovernmentPowerConstraint* is an index that ranges from 0 (no constraint on government power) to 1 (strict constraint on government power). The index is computed by accounting for various aspects of constraints on government power within the country.
OpenGovernment	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *OpenGovernment* is an index that ranges from 0 (closed government) to 1 (open government). The index is computed by accounting for various aspects of openness in the government within the country.
FundamentalRight	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *FundamentalRight* is an index that ranges from 0 (no fundamental rights) to 1 (significant fundamental rights). The index is computed by accounting for various aspects of fundamental rights within the country.
CivilJustice	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *CivilJustice* is an index that ranges from 0 (weak civil justice) to 1 (strong civil justice). The index is computed by accounting for various aspects of civil justice within the country.
CriminalJustice	The data is extracted from The World Justice Project (WJP) Rule of Law Index. *CriminalJustice* is an index that ranges from 0 (weak criminal justice) to 1 (strong criminal justice). The index is computed by accounting for various aspects of criminal justice within the country.
Regions	Our dataset consists of countries divided into 6 regions: Americas, Asia Pacific, Europe & Central Asia, Middle East & North Africa, Sub-Saharan Africa, and Western Europe/European Union
Income groups	Our data consists of countries divided into 4 income groups: High, Upper Middle, Lower Middle, and Low.

Table A2
Absence of Corruption and Regulatory Enforcement Investment (Robustness Test: Income level)

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption
RegulatoryEnforcement	0.658***	0.689***	0.404***
	(0.0778)	(0.0750)	(0.101)
Constant	0.228***	0.220***	0.304***
	(0.0537)	(0.0526)	(0.0547)
Observations	857	857	857
YearFE	NO	YES	YES
CountryFE	NO	NO	YES
IncomeFE	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the RegulatoryEnforcement, and this is a direct measure for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Column (1) do not include any fixed-effects, column (2) include year fixed-effects, and column (3) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A3
Absence of Corruption and Government Security Investment Measures (Robustness Test: Income level)

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
OrderSecurity	0.264***	0.276***	0.145**						
	(0.0582)	(0.0605)	(0.0672)						
GovernmentPowerConstraint				0.521***	0.524***	0.410***			
				(0.0577)	(0.0580)	(0.0668)			
OpenGovernment							0.264***	0.336***	0.236***
							(0.0439)	(0.0454)	(0.0509)
Constant	0.396***	0.398***	0.416***	0.262***	0.265***	0.277***	0.440***	0.411***	0.395***
	(0.0499)	(0.0505)	(0.0492)	(0.0405)	(0.0407)	(0.0398)	(0.0348)	(0.0346)	(0.0269)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
IncomeFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the OrderSecurity, columns (4)-(6) report results for the GovernmentPowerConstraint, and columns (7)-(9) report results for the OpenGovernment. These three are measures for the level of government security investment, and are indirect measures for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
FundamentalRight	0.402***	0.441***	0.279***						
	(0.0766)	(0.0770)	(0.0863)						
CivilJustice				0.515***	0.561***	0.234***			
				(0.0545)	(0.0563)	(0.0681)			
CriminalJustice							0.478***	0.572***	0.278***
							(0.0585)	(0.0606)	(0.0716)
Constant	0.328***	0.295***	0.342***	0.310***	0.286***	0.389***	0.357***	0.286***	0.364***
	(0.0542)	(0.0571)	(0.0547)	(0.0446)	(0.0443)	(0.0376)	(0.0412)	(0.0440)	(0.0398)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
CountryFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
IncomeFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Cluster	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY	COUNTRY

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the FundamentalRight, columns (4)-(6) report results for the CivilJustice, and columns (7)-(9) report results for the CriminalJustice. These three are measures for the level of justice rights investment, and are indirect measures for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Columns (1), (4), and (7) do not include any fixed-effects, columns (2), (5), and (8) include year fixed-effects, and columns (3), (6) and (9) include both year- and country-fixed effects. We further control for income levels across all columns. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A5
Absence of Corruption and Regulatory Enforcement Investment (Robustness Test: Region)

	1	2	3
Dependent Variable	AbsenceCorruption	AbsenceCorruption	AbsenceCorruption
RegulatoryEnforcement	0.624***	0.673***	0.649***
	(0.0654)	(0.0787)	(0.0756)
Constant	0.204***	0.185***	0.226***
	(0.0339)	(0.0419)	(0.0476)
Observations	857	857	857
YearFE	NO	YES	YES
RegionFE	YES	YES	YES
IncomeFE	NO	NO	YES
SE Cluster	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the RegulatoryEnforcement, and this is a direct measure for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Column (1) only include region fixed-effects, column (2) include both year- and region-fixed effects, and column (3) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A6
Absence of Corruption and Government Security Investment Measures (Robustness Test: Region)

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
OrderSecurity	0.218***	0.228***	0.252***						
	(0.0653)	(0.0666)	(0.0623)						
GovernmentPowerConstraint				0.468***	0.476***	0.491***			
				(0.0509)	(0.0516)	(0.0526)			
OpenGovernment							0.225***	0.299***	0.308***
							(0.0811)	(0.0806)	(0.0785)
Constant	0.381***	0.380***	0.392***	0.266***	0.265***	0.264***	0.410***	0.380***	0.398***
	(0.0440)	(0.0454)	(0.0305)	(0.0286)	(0.0287)	(0.0316)	(0.0424)	(0.0410)	(0.0278)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
RegionFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IncomeFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the OrderSecurity, columns (4)-(6) report results for the GovernmentPowerConstraint, and columns (7)-(9) report results for the OpenGovernment. These three are measures for the level of government security investment, and are indirect measures for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index".Columns (1), (4), and (7) only include region fixed-effects, columns (2), (5), and (8) include both year- and region-fixed effects, and columns (3), (6) and (9) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table A7
Absence of Corruption and Justice Rights Investment Measures (Robustness Test: Region)

Dependent Variable	1 AbsenceCorruption	2 AbsenceCorruption	3 AbsenceCorruption	4 AbsenceCorruption	5 AbsenceCorruption	6 AbsenceCorruption	7 AbsenceCorruption	8 AbsenceCorruption	9 AbsenceCorruption
FundamentalRight	0.341***	0.383***	0.405***						
	(0.0861)	(0.0867)	(0.0986)						
CivilJustice				0.524***	0.565***	0.528***			
				(0.0376)	(0.0492)	(0.0612)			
CriminalJustice							0.493***	0.592***	0.550***
							(0.0445)	(0.0436)	(0.0506)
Constant	0.316***	0.284***	0.283***	0.246***	0.226***	0.278***	0.306***	0.244***	0.291***
	(0.0535)	(0.0544)	(0.0789)	(0.0203)	(0.0240)	(0.0502)	(0.0200)	(0.0237)	(0.0403)
Observations	857	857	857	857	857	857	857	857	857
YearFE	NO	YES	YES	NO	YES	YES	NO	YES	YES
RegionFE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IncomeFE	NO	NO	YES	NO	NO	YES	NO	NO	YES
SE Cluster	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION	REGION

Notes: This table presents results of the panel regression at the country × year level. The data are restricted to 857 observations across 126 countries between 2012 and 2019. Columns (1)-(3) report results for the FundamentalRight, columns (4)-(6) report results for the CivilJustice, and columns (7)-(9) report results for the CriminalJustice. These three are measures for the level of justice rights investment, and are indirect measures for m, AbsenceCorruption is the corruption index, and these measures are all extracted from the "World Justice Project Rule of Law Index". Columns (1), (4), and (7) only include region fixed-effects, columns (2), (5), and (8) include both year- and region-fixed effects, and columns (3), (6) and (9) include both year- and region-fixed effects and also control for income levels. Standard errors are clustered at the country level across all columns and reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix 1

<u>Proof A</u>

Given the model set-up:

$$b = y + z$$

$$r_{g>0} > r_{g=0}$$

This means that the following is true:

$$0 < b \cdot r_{g=0} < y \cdot r_{g=0} + z \cdot r_{g>0} < b \cdot r_{g>0}$$

Furthermore, following the result of Proposition 3 given in chapter 1 and the domain of g is between 0 and 1:

$$b \cdot r_{g>0} < g \cdot R < R$$

Taken together, we show that the following is true:

$$y \cdot r_{g=0} + z \cdot r_{g>0} < R$$

$$y \cdot r_{g=0} + z \cdot r_{g>0} > 0$$

Proof B

Optimization problem is as follows:

$$\max_{z} \quad y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right) - b - [g \cdot v(z) \cdot R]$$

$$s.t. \quad b = y + z$$

Taking the first-order condition under constraint and setting the result to zero yields the following:

$$-\left(1 + r_{g=0}\right) + \left(1 + r_{g>0}\right) - \left[g \cdot \frac{\alpha}{z^*} \cdot \left(\frac{z}{z^*}\right)^{\alpha-1} \cdot R\right] = 0$$

$$\therefore \tilde{z} = \left[\frac{(z^*)^{\alpha} \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}}$$

Proof C

Optimization problem is as follows:

$$\max_{z} \quad y_{ext} \cdot (1 + r_{g=0}) + z_{ext} \cdot (1 + r_{g>0}) - b - [g \cdot \mu \cdot v(z) \cdot R]$$

$$s.t. \quad b = y_{ext} + z_{ext}$$

Taking the first-order condition under constraint and setting the result to zero yields the following:

$$-(1 + r_{g=0}) + (1 + r_{g>0}) - \left[g \cdot \frac{\alpha}{z^*} \cdot \left(\frac{z_{ext}}{z^*} \right)^{\alpha-1} \cdot R \right] = 0$$

$$\therefore \tilde{z}_{ext} = \left[\frac{(z^*)^{\alpha} \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot \mu \cdot R} \right]^{\frac{1}{\alpha-1}}$$

As μ takes the value between 0 and 1, this implies that the following is true:

$$\tilde{z} = \left[\frac{(z^*)^{\alpha} \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot R} \right]^{\frac{1}{\alpha-1}} < \left[\frac{(z^*)^{\alpha} \cdot (r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot \mu \cdot R} \right]^{\frac{1}{\alpha-1}} = \tilde{z}_{ext}$$

<u>Proof D</u>

$$\tilde{z}_{good} + \tilde{z}_{bad} = \left[\frac{\left(z_{0,good}^*\left(1-\left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)\right)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R \cdot \mu_{good}}\right]^{\frac{1}{\alpha-1}}$$

$$+ \left[\frac{\left(z_{0,bad}^*\left(1-\left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)\right)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R \cdot \mu_{bad}}\right]^{\frac{1}{\alpha-1}}$$

$$= \left[\frac{\left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot R}\right]^{\frac{1}{\alpha-1}} \left[\left(\frac{\left(z_{0,good}^*\left(1-\left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)\right)^\alpha}{\mu_{good}}\right)^{\frac{1}{\alpha-1}}\right.$$

$$\left.+ \left(\left(\frac{\left(z_{0,bad}^*\left(1-\left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)\right)^\alpha}{\mu_{bad}}\right)^{\frac{1}{\alpha-1}}\right)\right]$$

$\therefore$ the optimization problem can be redefined as follows:

$$\min_{m_{good},m_{bad}} \left[\left(\frac{\left(z_{0,good}^*\left(1-\left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)\right)^\alpha}{\mu_{good}}\right)^{\frac{1}{\alpha-1}} + \left(\left(\frac{\left(z_{0,bad}^*\left(1-\left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)\right)^\alpha}{\mu_{bad}}\right)^{\frac{1}{\alpha-1}}\right)\right]$$

$$s.t. \quad m = m_{good} + m_{bad}$$

Taking the first-order condition about m_{good} under constraint and setting the result to zero yields the following:

$$\frac{\alpha \cdot (1 - \theta) \cdot \left(-z_{0,good}^*\right)}{(\alpha - 1) \cdot m^*} \cdot \left[\frac{z_{0,good}^*}{\mu_{good}} \cdot \left(1 - \left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)\right]^{\frac{1}{\alpha-1}} \cdot \left(\frac{m_{good}}{m^*}\right)^{-\theta}$$

$$= \frac{\alpha \cdot (1 - \theta) \cdot \left(-z_{0,bad}^*\right)}{(\alpha - 1) \cdot m^*} \cdot \left[\frac{z_{0,bad}^*}{\mu_{bad}} \cdot \left(1 - \left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)\right]^{\frac{1}{\alpha-1}} \cdot \left(\frac{m_{bad}}{m^*}\right)^{-\theta}$$

$$\Rightarrow \left(z_{0,good}^*\right) \cdot \left[\frac{z_{0,good}^*}{\mu_{good}} \cdot \left(1 - \left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)\right]^{\frac{1}{\alpha-1}} \cdot \left(m_{good}\right)^{-\theta}$$

$$= \left(z_{0,bad}^*\right) \cdot \left[\frac{z_{0,bad}^*}{\mu_{bad}} \cdot \left(1 - \left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)\right]^{\frac{1}{\alpha-1}} \cdot \left(m_{bad}\right)^{-\theta}$$

$$\therefore \left(\frac{\mu_{bad}}{\mu_{good}}\right)^{\frac{1}{\alpha-1}} \left(\frac{z_{0,good}^*}{z_{0,bad}^*}\right)^{\frac{\alpha}{\alpha-1}} = \left[\frac{\left(1 - \left(\frac{m_{bad}}{m^*}\right)^{1-\theta}\right)}{\left(1 - \left(\frac{m_{good}}{m^*}\right)^{1-\theta}\right)}\right]^{\frac{1}{\alpha-1}} \cdot \left(\frac{m_{good}}{m_{bad}}\right)^{\theta}$$

Proof E

Regulators will choose to mandate *Regbonds* under ex-post setting if the expected cost under mandate is less than the cost without mandate, given as follows:

$$E\left(Cost_{with\ mandate}^{ex-post}\right) < E\left(Cost_{without\ mandate}^{ex-post}\right)$$

$$\Rightarrow \left[g \cdot v(\tilde{z}_{ext}) \cdot \left[X \cdot r_{reg} + (1 - \mu - x) \cdot R\right]\right] + \left[\left(1 - g \cdot v(\tilde{z}_{ext})\right) \cdot X \cdot r_{reg}\right]$$

$$< \left[g \cdot v(\tilde{z}_{ext}) \cdot \left[(1 - \mu) \cdot R\right]\right]$$

$$\therefore r_{reg} < g \cdot v(\tilde{z}_{ext})$$

<u>Proof F</u>

Regulators will choose to mandate *Regbonds* under ex-ante setting if the expected cost under mandate is less than the cost without mandate, given as follows:

$$E(Cost^{ex-ante}_{with\ mandate}) < E(Cost^{ex-ante}_{without\ mandate})$$

$$\Rightarrow \left[g \cdot v(\tilde{z}_{reg}) \cdot \left[X \cdot r_{reg} + (1 - \mu - x) \cdot R\right]\right] + \left[\left(1 - g \cdot v(\tilde{z}_{reg})\right) \cdot X \cdot r_{reg}\right]$$

$$< \left[g \cdot v(\tilde{z}_{ext}) \cdot \left[(1 - \mu) \cdot R\right]\right]$$

$$\therefore X < \frac{g \cdot (1 - \mu) \cdot R \cdot \left[v(\tilde{z}_{ext}) - v(\tilde{z}_{reg})\right]}{r_{reg} - g \cdot v(\tilde{z}_{reg})}$$

<u>Proof G</u>

Given the following:

$$z_{0,good}^* < z_{0,bad}^*$$

$$\mu_{good} > \mu_{bad}$$

It is easy to see that the following is true:

$$z_{good}^* < z_{bad}^*$$

$$\tilde{z}_{good} < \tilde{z}_{bad}$$

With the conviction probability density function as follows:

$$v(\tilde{z}_i) = \begin{cases} \left(\dfrac{\tilde{z}_i}{z_i^*}\right)^\alpha & , \quad \tilde{z}_i < z_i^* \text{ and } \alpha > 1 \\ 1 & , \quad \tilde{z}_i \geq z_i^* \end{cases}, \qquad where \ i = bad, good$$

It is difficult to determine if the good or bad firm has a larger conviction probability when other parameters remain unchanged. However, we establish a robust relationship with the following:

$$\frac{z_{0,good}^*}{\mu_{good}} < \frac{z_{0,bad}^*}{\mu_{bad}}$$

$$\Rightarrow \frac{(r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot (\mu_{good} + x) \cdot R} \cdot \frac{\left(z_{0,good}^*\right)^\alpha}{z_{0,good}^*} < \frac{(r_{g>0} - r_{g=0})}{\alpha \cdot g \cdot (\mu_{bad} + x) \cdot R} \cdot \frac{\left(z_{0,bad}^*\right)^\alpha}{z_{0,bad}^*}$$

$$\Rightarrow \frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left(z_{0,good}^*\right)^\alpha}{\alpha \cdot g \cdot (\mu_{good} + x) \cdot R}\right)}{z_{0,good}^*} < \frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left(z_{0,bad}^*\right)^\alpha}{\alpha \cdot g \cdot (\mu_{bad} + x) \cdot R}\right)}{z_{0,bad}^*}$$

As established earlier, in an asymmetric information setting, the following holds:

$$m_{good} = m_{bad}$$

$$\Rightarrow \left(1 - \Delta z_{reg,good}^*\right) = \left(1 - \Delta z_{reg,bad}^*\right)$$

Taken together, this implies the following:

$$\Rightarrow \frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left[(z^*_{0,good}) \cdot (1 - \Delta z^*_{reg,good})\right]^{\alpha}}{\alpha \cdot g \cdot (\mu_{good} + x) \cdot R}\right)}{z^*_{0,good} \cdot (1 - \Delta z^*_{reg,good})}$$

$$< \frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left[(z^*_{0,bad}) \cdot (1 - \Delta z^*_{reg,bad})\right]^{\alpha}}{\alpha \cdot g \cdot (\mu_{bad} + x) \cdot R}\right)}{z^*_{0,bad} \cdot (1 - \Delta z^*_{reg,bad})}$$

$$\Rightarrow \left[\left(\frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left[(z^*_{0,good}) \cdot (1 - \Delta z^*_{reg,good})\right]^{\alpha}}{\alpha \cdot g \cdot (\mu_{good} + x) \cdot R}\right)}{z^*_{0,good} \cdot (1 - \Delta z^*_{reg,good})}\right)^{\frac{1}{\alpha-1}}\right]^{\alpha}$$

$$< \left[\left(\frac{\left(\dfrac{(r_{g>0} - r_{g=0}) \cdot \left[(z^*_{0,bad}) \cdot (1 - \Delta z^*_{reg,bad})\right]^{\alpha}}{\alpha \cdot g \cdot (\mu_{bad} + x) \cdot R}\right)}{z^*_{0,bad} \cdot (1 - \Delta z^*_{reg,bad})}\right)^{\frac{1}{\alpha-1}}\right]^{\alpha}$$

$$\therefore v(\tilde{z}_{good}) < v(\tilde{z}_{bad})$$

<u>Proof H</u>

A firm will choose to post *Regbonds* under a voluntary setting if the expected net payoff from posting is more than that of not posting, given as follows:

$$E\left(Net\ Payoff_{with\ posting}\right) > E\left(Net\ Payoff_{without\ posting}\right)$$

$$\Rightarrow \left\{ \left[g \cdot v(\tilde{z}_{reg}) \cdot \left[X \cdot r_{reg} + \tilde{y}_{reg} \cdot r_{g=0} + \tilde{z}_{reg} \cdot r_{g>0} - (\mu + x) \cdot R \right] \right] \right.$$

$$\left. + \left[\left(1 - g \cdot v(\tilde{z}_{reg})\right) \cdot \left(X \cdot r_{reg} + \tilde{y}_{reg} \cdot r_{g=0} + \tilde{z}_{reg} \cdot r_{g>0} \right) \right] \right\}$$

$$> \left\{ \left[g \cdot v(\tilde{z}_{ext}) \cdot \left[\tilde{y}_{ext} \cdot r_{g=0} + \tilde{z}_{ext} \cdot r_{g>0} - \mu \cdot R \right] \right] \right.$$

$$\left. + \left[\left(1 - g \cdot v(\tilde{z}_{ext})\right) \cdot \left(\tilde{y}_{ext} \cdot r_{g=0} + \tilde{z}_{ext} \cdot r_{g>0} \right) \right] \right\}$$

$$\Rightarrow X \cdot r_{reg} + \tilde{y}_{reg} \cdot r_{g=0} + \tilde{z}_{reg} \cdot r_{g>0} - g \cdot v(\tilde{z}_{reg}) \cdot \left[(\mu + x) \cdot R \right]$$

$$> \tilde{y}_{ext} \cdot r_{g=0} + \tilde{z}_{ext} \cdot r_{g>0} - g \cdot v(\tilde{z}_{ext}) \cdot \mu \cdot R$$

$$\Rightarrow r_{reg} > \frac{1}{X} \cdot \left\{ g \cdot R \left[v(\tilde{z}_{reg}) \cdot (\mu + x) - v(\tilde{z}_{ext}) \cdot \mu \right] \right.$$

$$+ \left[\left(\tilde{z}_{ext} \cdot r_{g>0} \right) + \left(b \cdot r_{g=0} \right) - \left(\tilde{z}_{ext} \cdot r_{g=0} \right) \right]$$

$$\left. - \left[\left(\tilde{z}_{reg} \cdot r_{g>0} \right) + \left(b \cdot r_{g=0} \right) - \left(\tilde{z}_{reg} \cdot r_{g=0} \right) \right] \right\}$$

$$\Rightarrow r_{reg} > \frac{g \cdot R \left[v(\tilde{z}_{reg}) \cdot (\mu + x) - v(\tilde{z}_{ext}) \cdot \mu \right] + \left[(r_{g>0} - r_{g=0}) \cdot (\tilde{z}_{ext} - \tilde{z}_{reg}) \right]}{X}$$

$$+ \tilde{y}_{reg} \cdot r_{g=0} + \tilde{z}_{reg} \cdot r_{g>0} - g \cdot v(\tilde{z}_{reg}) \cdot \left[(\mu + x) \cdot R \right]$$

$$> \tilde{y}_{ext} \cdot r_{g=0} + \tilde{z}_{ext} \cdot r_{g>0} - g \cdot v(\tilde{z}_{ext}) \cdot \mu \cdot R$$

Recall our substitution where:

$$v(\tilde{z}_i) = \left(\frac{\tilde{z}_i}{z^*} \right)^{\alpha}, where\ i = ext, reg$$

$$\tilde{z}_i = \left[\frac{(z^*)^{\alpha} \cdot \left(r_{g>0} - r_{g=0} \right)}{\alpha \cdot g \cdot (\mu + I_i) \cdot R} \right]^{\frac{1}{\alpha - 1}}, where\ i = ext, reg$$

$$I_i = \begin{cases} x & , \ i = reg \\ 0 & , \ i = ext \end{cases}$$

Therefore, applying our substitution and with some simplification, we yield the following:

$$\therefore r_{reg} > \frac{\left(\left((z^*) \cdot (r_{g>0} - r_{g=0})\right)^{\frac{\alpha}{\alpha-1}}\right) \cdot \left((\mu + x)^{\frac{1}{1-\alpha}} - (\mu)^{\frac{1}{1-\alpha}}\right) \cdot \left(\frac{1}{\alpha} - 1\right)}{X \cdot \left((\alpha g R)^{\frac{1}{\alpha-1}}\right)}$$

<u>Proof I</u>

Recall the following:

$$q = \frac{\left(\left((z^*) \cdot (r_{g>0} - r_{g=0})\right)^{\frac{\alpha}{\alpha-1}}\right) \cdot \left((\mu + x)^{\frac{1}{1-\alpha}} - (\mu)^{\frac{1}{1-\alpha}}\right) \cdot \left(\frac{1}{\alpha} - 1\right)}{X \cdot \left((\alpha g R)^{\frac{1}{\alpha-1}}\right)}$$

$$\Rightarrow \frac{dq}{dz^*} = \left[\frac{\alpha \cdot (r_{g>0} - r_{g=0})^{\frac{\alpha}{\alpha-1}} \cdot (g \cdot R)^{\frac{1}{1-\alpha}} \cdot (z^*)^{\frac{1}{\alpha-1}}}{(\alpha - 1) \cdot X}\right] \cdot \left[(\mu + x)^{\frac{1}{1-\alpha}} - (\mu)^{\frac{1}{1-\alpha}}\right]$$

$$\cdot \left[\left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha-1}} \cdot \left(\frac{1}{\alpha} - 1\right)\right]$$

Since the first term is positive, while the second and third terms are negative,

$$\therefore \frac{\partial q}{\partial z^*} > 0$$

Recall the following:

$$q = \frac{\left(\left((z^*) \cdot (r_{g>0} - r_{g=0})\right)^{\frac{\alpha}{\alpha-1}}\right) \cdot \left((\mu + x)^{\frac{1}{1-\alpha}} - (\mu)^{\frac{1}{1-\alpha}}\right) \cdot \left(\frac{1}{\alpha} - 1\right)}{X \cdot \left((\alpha g R)^{\frac{1}{\alpha-1}}\right)}$$

$$\Rightarrow \frac{dq}{d\mu} = \left[\frac{(r_{g>0} - r_{g=0})^{\frac{\alpha}{\alpha-1}} \cdot (g \cdot R)^{\frac{1}{1-\alpha}} \cdot (z^*)^{\frac{\alpha}{\alpha-1}}}{X}\right] \cdot \left[\left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha-1}} \cdot \left(\frac{1}{\alpha} - 1\right)\right]$$

$$\cdot \left[(\mu + x)^{\frac{\alpha}{1-\alpha}} - (\mu)^{\frac{\alpha}{1-\alpha}}\right] \cdot \left[\frac{1}{1 - \alpha}\right]$$

Since the first term is positive, while the second, third and fourth terms are negative,

$$\therefore \frac{\partial q}{\partial \mu} < 0$$

Aligning Interests between Shareholders and Managers: *Regbonds*

Abstract

We incorporate agency problem into the gray project investments model. We model this with risk preferences and compensation ratio. This allows us to see that gray project investment decreases and increases in the relative risk aversion parameter and compensation ratio parameter, respectively. We conduct data analysis on a testable hypothesis of our model and obtain supportive empirical evidence which lends credence to our model. Our paper focuses on the micro level and shows that *Regbonds* can help shareholders identify the underlying risk preference of managers and take corrective and preventive actions under the ex-post and ex-ante settings, respectively. Furthermore, we show that under certain conditions, *Regbonds* can better align interests between shareholders and managers in terms of gray project investments. This ensures the investments in gray projects undertaken by managers will be close to the exact level preferred by shareholders, with no over or under investment problems (i.e. manager-optimal is equivalent to firm-optimal gray project investments).

1. Introduction

Jensen & Meckling (1976) coined the term agency costs in their seminal paper. They proposed that this arises from the separation of ownership and control. In chapter 2, we have shown that *Regbonds* can help to mitigate the aggregate gray project investments at the macro level. We term gray projects as investment projects that firms are committing that they might (or might not) know are illegal investment projects. Furthermore, such an ambiguity is exacerbated due to the complex nature of investment activities and even more complex regulatory climate. This stands in stark contrast against individual crimes where it is generally known that hurting others, stealing, abusing verbally, etc, are crimes. The natural implication is that the formal definition of gray investment projects is that the legality is ambiguous.[1] A key assumption used in chapters 1 and 2 is that the incentives between shareholders and managers within each firm are perfectly aligned.

In this paper, we relax this assumption by looking at how incentives between shareholders and managers can be misaligned. We extend the model built in chapter 1 by showing that incentives can be misaligned when managers have non-risk-neutral utilities. Furthermore, we also show that when the proportion of upside gain is not equivalent to that of downside loss, agency problems arise as well. After relaxing the assumption, we show that managers will engage in suboptimal behavior when they will either over- or under-allocate investments towards gray projects. We show that this is true in an empirical correlation analysis, where firms with a higher compensation ratio (given by higher stock compensation) are associated with higher gray project investments (given by the event of being bailed out by the government). We continue to show that stock compensation can mitigate the underinvestment behavior by risk averse managers, but will worsen the overinvestment problem concerning risk seeking managers. This is because shareholders are unable to determine the underlying risk preference of managers.

In response to this, the paper uses *Regbonds*, to help mitigate the agency problem. The *Regbonds* function like a bond, where the company that posts it will receive cash while the counterparty will receive coupon payments in return for putting up the money. In this

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[1] Notice that gray investment projects are not risky projects. In our definition, risk in investment projects are determined by the volatility of future returns while gray projects are determined by their underlying legality.

case, the counterparty will be the managers within the firm. Unlike traditional bonds, *Regbonds* will not be used to finance firm's capital investments. Instead, *Regbonds* will be set aside in escrow and the bondholders (i.e. managers) will receive their principal upon maturity given that no trigger event occurs. In the case of *Regbonds*, the trigger event will be when the firm gets convicted for their gray project investments. This implies the *Regbonds* will be used to pay off the financial loss when firms get convicted.

This paper takes a micro view and shows that *Regbonds* can act as a signaling mechanism on the underlying investment behavior of managers. In the ex-post setting, under certain conditions, we show that *Regbonds* will allow shareholders to undertake corrective action. This mitigates the overinvestment problem without worsening the underinvestment problem. In the ex-ante setting, we show that *Regbonds* allow shareholders to take preventive action. Furthermore, we show that under an ex-ante setting and under certain assumptions, by first setting a high compensation ratio and subsequently readjusting this ratio based on the subscription rate, *Regbonds* can better align interests between shareholders and managers. This ensures all managers will invest at the firm-level optimal gray project investments, or any level as required by the shareholders.

The rest of the paper is organized as follows. Section 2 is the literature review. Section 3 lays out the basic model set-up and incorporates agency problem. Section 4 introduces *Regbonds* and conducts the analyses under an ex-post and ex-ante setting which allow the shareholders to undertake corrective and preventive actions, respectively. Section 5 provides some empirical analyses. Section 6 concludes.

2. Literature Review

In chapter 2, we have shown that *Regbonds* can help bring the aggregate gray project investments in the macro economy closer to the optimal. We have also shown that *Regbonds* can act as a signaling mechanism for regulators to more efficiently direct deterrence investments. However, the underlying assumption used was that no agency issue exists between shareholders and managers. Jensen & Meckling (1976) wrote the seminal paper that suggests the existence of agency problem arising from the separation of ownership and control.

This is costly to the firm as a separation of ownership and control allows managers to (i) extract private benefits (i.e. abscond with the money, consume perquisites, empire building, or pursue pet projects), (ii) be entrenched (i.e. stay on the job even when they are no longer capable to run the firm) and (iii) reinvest free cash flow instead of paying them out to shareholders (Jensen, 1986).

Boycko, Shleifer, & Vishny (1996) documented empirically that the upper bound of agency costs can go as high as 99% of firm value. Gormley & Matsa (2016) used the setting of Business Combination (BC) laws and found that as takeover threats are reduced, managers tend to take on more diversifying acquisitions that destroy equity value. This is against shareholders' interest but managers do this as the diversification lowers distress risk and is in the interests of the managers. Therefore, it is widely documented, both theoretically and empirically, within traditional literature that agency costs are costly to the firm as incentives between shareholders and managers are misaligned.

Therefore, in this paper, we weaken the assumption of a perfect alignment of incentives between shareholders and managers. We then show, at the micro level, agency problems can lead to suboptimal firm-level gray project investments by managers (i.e. over or under investments) and it is the first key contribution of our paper.

There exists a huge literature that aims to solve agency problem between shareholders and managers. The solutions can be broadly divided into those (i) without corporate governance and (ii) with corporate governance. On the one hand, agency problems can be solved without corporate governance mainly via (i) reputation building and (ii) excessive investors' optimism. Under reputation building, managers will choose to repay investors as they want to return to the capital market and raise funds again in the future (Kreps, 1990). However, this explanation runs into a backward recursion problem, where managers will rationally default sometime in the future when they no longer need to return to the capital market, and leads to no financing ex-ante. Therefore, this solution is imperfect. Under excessive investors' optimism, investors get excited about companies and will provide financing without much thought on getting their money back (De Long et al., 1989). However, this method is also imperfect as it does not prevent managers from expropriating some wealth.

On the other hand, agency problems can be solved with corporate governance where solutions come in the form of (i) contracts, (ii) legal protection, (iii) concentrated ownership, (iv) institutional investors, (v) board of directors, and (vi) disciplinary takeovers. First, contracts can be established between owners and managers to align the interests of both parties and minimize agency problems. Jensen & Meckling (1976) proposed that contracts can take the form of complete contracts, contingent contracts or incentive contracts. They proposed that complete contracts are unrealistic, as it is not possible to spell out all states of nature and the corresponding actions to undertake, while contingent contracts are ironic, as managers are hired to handle unexpected issues that come up. They proposed that incentive contracts are more reasonable as these can take many forms, such as share ownership or stock options, and can help to align interests of both owners and managers in maximizing firm value. However, Jensen & Murphy (1990) found that the sensitivity of pay to performance is too low to incentivize positive actions from managers. Yermack (1997) also found evidence of self-dealing, where managers tend to receive stock option grants shortly before announcements of good news, and tend to delay such grants until after announcements of bad news. In our paper, we show theoretically that high levels of stock compensation might lead to overinvestments in gray projects. Furthermore, we document empirically that high levels of stock compensation is associated with the firm being bailed out by the government (i.e. our proxy for the firm's gray project investments).

Next, legal protection might not be perfect in mitigating agency issues as well. Shleifer & Vishny (2012) argued that these rights are only as good as the law that protects them. A lack of legal protection deters small investors from entering the capital market for fear of expropriation. In support of the argument, La Porta et al. (1997) documented that countries with poorer investor protections have smaller and narrower capital markets. Third, concentrated ownership is imperfect as well as it might give rise to an alternate type of agency problem where large investors can expropriate from other smaller investors, managers and employees (Jensen & Meckling, 1976). Baek, Kang, & Lee (2006) documented empirical support for this where large investors engage in tunneling activities.

Institutional investors can affect corporate governance of the firm by taking different forms, such as hedge funds, mutual funds, passive funds, venture capitalists and blockholders. Empirical evidence on the effectiveness of institutional investors is mixed. Brav, Jiang, & Kim (2015) documented that hedge fund activists create value. Specifically, they found that plant productivity deteriorates prior to hedge fund intervention, the deterioration triggers hedge fund intervention and productivity improves significantly after the hedge fund intervention. They also documented that capital redeployment by hedge fund activists is an important channel for value creation, as plants sold after intervention still maintain improved productivity under their new ownership. Cvijanović, Dasgupta, & Zachariadis (2016) documented that mutual fund activism's effectiveness is limited by the fund's business ties with portfolio firms. They found that stronger business ties is associated with a higher percentage of voting with managers in shareholder proposals (especially those that pass or fail by relatively narrow margins). Hence, this suggests that stronger business ties with portfolio firms might lead to weaker monitoring efforts by mutual funds. Appel, Gormley, & Keim (2016) documented that higher passive institutional ownership help to improve a firm's corporate governance mechanisms that are less costly; while Schmidt & Fahlenbrach (2017) documented that higher passive institutional ownership will worsen a firm's corporate governance mechanisms that require more monitoring and are more costly. The latter paper provided a reconciliation, where they suggested that the former paper focused on corporate governance mechanisms that are less costly while the latter paper focused on corporate governance mechanisms that are more costly and require stronger monitoring. Taken together, this means that higher passive institution ownership will improve basic corporate governance mechanisms but worsen in corporate governance mechanisms that are more costly. Bernstein, Giroud, & Townsend (2015) documented the effectiveness of monitoring by venture capitalists (VCs). They documented the causal relation where higher monitoring by VCs is associated with an increase in the portfolio firm's innovation and likelihood of a successful exit. Kang, Li, & Oh (2017) went a step further and showed that the effectiveness of VC monitoring improves with greater concentration of VC investors. They documented that entrepreneurial firms whose VC investors are closely located to each other experience less intense staging rounds, receive a smaller amount of convertible securities, are less likely to have a VC director on their board and have larger IPO

valuation. Kang, Luo, & Na (2018) focused on institutional investors with multiple blockholdings. The effect of multiple blockholdings is unclear due to competing hypothesis, where the limited attention hypothesis suggests that institutional investors are distracted from monitoring while the enhanced capabilities hypothesis suggests that institutional investors will have more resources to engage in improved monitoring efforts. Their paper employed the residuals approach, by analyzing the residual number of blockholders that are not attributable to fund size. They found that the residual number of blockholders is positively associated with improvements in corporate governance measures and provide support for the enhanced capabilities argument.

Fama & Jensen (1983) predicted that the market for outside directorship incentivizes outside directors to develop their reputation as experts in monitoring. Hence, the prediction is that busy directors make for good monitors, as the reason that they are busy is because they are good monitors. However, the alternative view is that busy directors are bad monitors as they are distracted from monitoring due to being busy. Ferris, Jagannathan, & Pritchard (2003) defined a busy board based on the average number of board seats held by outside directors and found insignificant results between busy boards and firm performance. Fich & Shivdasani (2006) employed a different definition, where busy directors are directors who serve on 3 or more boards, while busy boards are boards where more than 50% of outside directors are busy. They found that firms with busy boards are associated with weaker firm performance. Hence, this shows that busy boards are poor monitors and provides support for the alternative hypothesis.

Lel & Miller (2015) employed the setting of staggered initiation of takeover laws across countries and documented that the threat of takeover does enhance managerial discipline and the effect is stronger if ex-ante corporate governance of the firm is weak. Specifically, they found that poorly performing firms are more likely to be subjected to takeovers and the directors of acquired firm will more likely be replaced. In response, directors engage in higher managerial discipline to reduce the likelihood of disciplinary takeover where they will likely be replaced. Taken together, this provides evidence that the threat of disciplinary takeover does enhance firm's managerial discipline and corporate governance.

In response, the second key contribution of our paper is in providing an alternative solution that solves the agency problems between shareholders and managers. Specifically, *Regbonds* can help managers internalize the costs of their decisions and act as a signaling mechanism to shareholders on the underlying behavior of the manager. We show that under predetermined conditions, shareholders are able to identify how much to pay each manager to ensure all managers allocate gray project investments that are at the firm-level optimal. Our results hold even under different risk preferences across managers and an information asymmetric setting. Furthermore, this paper solves agency problems associated with gray project investments only. This makes for a potential avenue for future research where *Regbonds* can be tweaked to solve other problems associated with agency costs.

Our paper also contributes to the vast crime and punishment literature. Becker's (1968) seminal paper on crime punishment developed an economic model that determines optimal policies that minimize criminal behavior by individuals. This gave rise to many follow-up papers that expanded on his paper that helps to develop the notion that individuals engage in criminal activities as an economic choice (Ehrlich, 1973; Tittle & Rowe, 1974; Block & Heineke, 1975; Myers Jr., 1983; Grogger, 1991). However, there is a lack of papers that analyze gray project investments within firms (Shleifer & Wolfrenzon, 2002). Chapter 1 provides a sound mathematical model that sheds novel insights and helps to explain real-world behavior of firms. Chapter 2 proposes *Regbonds* and shows how it can mitigate aggregate gray project investments in the macro economy. In our paper, we focus on bridging the gap of agency problems at the micro level and show how *Regbonds* can align interests between shareholders and managers.

3. Agency Problem and Gray Project Investments

Chapter 1 has provided a framework that analyzes firm's gray project investment behavior while chapter 2 has highlighted the importance of *Regbonds* in mitigating gray project investments within the ecosystem on a macro-perspective. However, both papers assume that the incentives between managers and shareholders are perfectly aligned in conducting their analyses.

We note that more often than not, agency problems are prevalent in the real-world. Therefore, this paper provides a better understanding of how agency problems between shareholders and managers can affect the gray project investments made within a firm.

This section begins by laying out the model used for analysis followed by a quantitative discussion on two mechanisms on how incentives between managers and shareholders can be misaligned: (i) risk preference and (ii) compensation package.

3.1 Model Set-up and Assumptions

We begin our analyses by borrowing the framework used in chapter 1, where a firm has a fixed investment budget. This budget will be allocated between two investment projects, a legal investment project and a gray investment project denoted as $P_{g=0}$ and $P_{g>0}$ respectively. Furthermore, the manager will make this allocation in place of the shareholder. The budget constraint is as follows:

$$b = y + z,$$

where b is the fixed investment budget, y is the investment in $P_{g=0}$, and z is the investment in $P_{g>0}$. Furthermore, g is defined as the probability of the investment project being illegal. The expected return on investment in $P_{g=0}$ and $P_{g>0}$ is assumed to be known ex-ante and is denoted by $r_{g=0}$ and $r_{g>0}$ respectively.

For the gray project investment undertaken by the firm, given the project turns out to be illegal, there is a likelihood of conviction that we define as the conviction probability and the probability function is denoted as $v(z)$ and is defined as follows:

$$v(z) = \begin{cases} \left(\dfrac{z}{z^*}\right)^{\alpha} & , \quad z < z^* \text{ and } \alpha > 1 \\ 1 & , \quad z \geq z^* \end{cases},$$

where z is the gray project investment, z^* is the upper-limit of gray project investments, and α is a firm specific variable that captures the firm's characteristics. Furthermore, a firm that is convicted for their gray project investments will be subjected to a financial penalty denoted as R. As discussed in chapter 2, the firm internalizes a portion μ of the

financial loss while the remaining portion is borne by external stakeholders within the ecosystem.

Taken together, this yields the following:

$$E(Revenue) = y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right),$$

$$E(Cost) = b + [g \cdot v(z) \cdot \mu \cdot R].$$

The standard optimization problem is thus:

$$\max_{z} \quad E(Revenue) - E(Cost)$$

$$s.t. \quad b = y + z.$$

Solving the optimization problem, we determine the optimal investments in $P_{g=0}$ and $P_{g>0}$, denoted as $\tilde{y}$ and $\tilde{z}$ respectively, as follows:

$$\tilde{y} = b - \tilde{z}$$

$$\tilde{z} = \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot \mu \cdot R} \right]^{\frac{1}{\alpha - 1}}.$$

(Proof A)

Therefore, when there are no incentives misalignment between shareholders and managers, the managers will allocate the investment budget optimally where managers will allocate $\tilde{y}$ and $\tilde{z}$ to investment projects $P_{g=0}$ and $P_{g>0}$, respectively, and this is in line with the shareholders' interests.

3.2 Risk Preferences

In the earlier section, we determine that when there are no incentive misalignment, managers will allocate the investment budget in the proportion that is optimal for the firm. However, when the risk preference of managers are different from that of the firm, incentive misalignment arises and managers will seek to maximize their non-risk neutral expected utility.

In order to determine the impact of risk preference on manager's investment allocation behavior, we assume that the manager receives the full payoff that arises from the investments made. Likewise, the losses incurred are borne solely by the manager as well. This will help to keep the analysis mathematically tractable and isolate the impact on allocation behavior solely on the difference in risk preference between the shareholders and the manager. This assumption will be relaxed in the subsequent section to allow for a more comprehensive understanding on the impact of agency problem on a firm's gray project investment. Figure 1 plots the net payoff to manager under the risk-preference setting.

[Place Figure 1 about here]

Therefore, the expected utility function for the manager is defined as follows:

$$E[U(w)] = [gv(z)] \cdot U(h - \mu R) + [1 - gv(z)] \cdot U(h),$$

$$h = y \cdot r_{g=0} + z \cdot r_{g>0},$$

where w is the payoff to the manager, and $U(w)$ is the associated utility function for the manager. The optimization problem for a rational manager will be to maximize his or her expected utility subjected to constraint, given as follows:

$$\max_{z} \quad E[U(w)]$$

$$s.t. \quad b = y + z.$$

Assuming that the utility function is additive, we show that the general form of our result is as follows:

$$\tilde{y}_{manager} = b - \tilde{z}_{manager},$$

$$\tilde{z}_{manager} = \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0}) \cdot U'(h)}{\alpha \cdot g \cdot \mu \cdot R} \right]^{\frac{1}{\alpha-1}}.$$

(Proof B)

Next, we assume an isoelastic (CRRA) utility function to define the manager's utility as follows:[2]

$$U(w) = \frac{(w)^{1-\eta}}{1-\eta} \quad , \quad w \neq 1,$$

$$\eta = \begin{cases} < 0 & , for\ risk-seeking\ agents\ (RS) \\ = 0 & , for\ risk-neutral\ agents\ (RN), \\ > 0 & , for\ risk-averse\ agents\ (RA) \end{cases}$$

where η is the relative risk aversion parameter. This yields the following result for the optimal gray project allocation by the manager under a CRRA utility function:

$$\tilde{z}_{manager} = \tilde{z} \cdot h^{-\frac{\eta}{\alpha-1}}.$$

(Proof C)

Proposition 1: When the manager is risk-neutral, it is easy to see that the solution when the manager maximizes his expected utility is exactly the solution when the firm maximizes profits, where:

$$\lim_{\eta \to 0} \tilde{z}_{manager,RN} = \tilde{z}$$

Proposition 2: We show that the gray project investments allocated by the manager decreases in the relative risk aversion parameter, where:

$$\frac{\partial z}{\partial \eta} < 0$$

(Proof D)

Our first result implies that when the manager is risk-neutral (i.e. the same as the firm), there is no agency problem and the optimal solution reached by the manager is the same as that reached by the firm. Our second result shows that a mismatch in risk preference between the manager and shareholders leads to a suboptimal allocation of investment

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[2] CRRA parameterization is popular for fitting utility functions in empirical economics as well as psychology because of its good fit to experimental data (Wakker, 2008). We note that the CRRA utility function is not additive but our focus here is on the relative risk aversion parameter and is the reason why we use the CRRA.

budget towards investment projects by managers. Specifically, we show that the managers underinvest in gray project investments when these firm managers are risk averse agents, and this level of underinvestment increases as the firm managers become more risk averse. Likewise, we also show that the managers overinvest in gray project investments when these firm managers are risk seeking agents, and the level of overinvestments increases as the firm managers become more risk seeking.

In order to show that our results are robust, we repeat the analysis above with the exponential (CARA) utility function to define the manager's utility, as follows:

$$U(w) = \begin{cases} \dfrac{1 - e^{-\kappa w}}{\kappa} & \kappa \neq 0 \\ w & \kappa = 0 \end{cases},$$

$$\kappa = \begin{cases} < 0 & , for\ risk - seeking\ agents\ (RS) \\ = 0 & , for\ risk - neutral\ agents\ (RN), \\ > 0 & , for\ risk - averse\ agents\ (RA) \end{cases}$$

where κ is the degree of risk-preference. This yields the following result for the optimal gray project allocation by the manager under a CARA utility function:

$$\tilde{z}_{manager} = \begin{cases} \tilde{z} \cdot \left(e^{-\frac{\kappa h}{\alpha - 1}} \right) & \kappa \neq 0 \\ \tilde{z} & \kappa = 0 \end{cases}$$

Despite using a different utility function, we see that our results from Propositions 1 and 2 continue to hold (Proof E). Specifically, we see that when the manager is risk-neutral, the optimal gray project investments made by managers are equivalent to the firm optimal (i.e. Proposition 1). Furthermore, we also see that the condition given in Proposition 2 continues to hold with the exponential utility function. This ties in neatly with our earlier result where suboptimal allocation of investment budget arises when there exists a mismatch in risk preference between shareholders and the manager. Moving forward, our subsequent analyses continue to assume a CRRA utility function due to its characteristic of being a good fit to experimental data in both empirical economics and psychology (Wakker, 2008).

Taken together, we show that managers who are risk-seeking or risk-averse will overinvest and underinvest in gray project investments relative to the optimal amount

preferred by the firm, respectively. Our results remain robust to using the CARA utility function. This phenomenon is essentially an agency problem, where managers will prioritize their expected utility above that of the shareholders and make decisions accordingly.

3.3 Compensation Mechanism

In the previous section, we saw that a risk-averse or risk-seeking manager will lead to a suboptimal allocation of the firm's investment budget as they prioritize their expected utility above that of the firm. A similar phenomenon has been documented in prior literature and thus shareholders have sought to mitigate this agency problem by structuring compensation mechanism to better align the interests between shareholders and managers.

In this section, we seek to analyze the impact of compensation mechanism on the agency problem. Similar to the previous section, in order to isolate the effect arising from the compensation mechanism, we assume that the manager's risk preference is exactly the same as that of the shareholder (i.e. the manager is risk neutral and seeks to maximize his or her payoff). In our analysis, we assume that the observation of the financial penalty event occurs at the end of the period and immediately after the returns from the investments are paid off. The implication is that the positive cashflow arising from the investments will always be paid out. Immediately thereafter, given that the financial penalty event occurs, the financial penalty will be paid out and a negative cashflow arises. Figure 2 plots the payoff timeline to the manager.

[Place Figure 2 about here]

Specifically, d is the proportion of the cashflow that will be received or borne by the manager in times of positive and negative cashflow, respectively, $\varDelta t$ is a small change in time t. We further define the proportion d and compensation ratio λ as follows:

$$d = \begin{cases} d_1 & , \quad Cashflow > 0 \\ d_2 & , \quad Cashflow < 0 \end{cases}$$

$$\lambda = \frac{d_1}{d_2}.$$

Our model implies when a firm gets convicted, the firm will yield negative return and this ties in with Proposition 1 in chapter 2. Conversely, if the firm does not get convicted, the implicit result is that the firm will yield a positive return. This is given by:

$$yr_{g=0} + zr_{g>0} - \mu R < 0,$$

$$yr_{g=0} + zr_{g>0} > 0.$$

Thus, the expected utility for the manager under the compensation-mechanism model is as follows:[3]

$$E[U(w)] = d_1 \cdot \left(yr_{g=0} + zr_{g>0} \right) - d_2 \cdot [gv(z)] \cdot \mu R.$$

Proposition 3: We can easily see that the following condition holds:

$$\frac{\partial E[U(w)]}{\partial d_1} > 0$$

$$\frac{\partial E[U(w)]}{\partial d_2} < 0$$

Our result implies that the manager expected utility increases in d_1 and decreases in d_2. This result implies that a risk-neutral manager who seeks to maximize his or her expected payoff will prefer to receive payouts at greater proportions (when payoffs are positive) and prefer to bear the financial losses at smaller proportions (when payoffs are negative).

Next, we solve the optimization problem for a rational manager given as follows:

$$\max_{z} \quad E[U(w)]$$

[3] Our prior assumption in this section is that the manager's risk preference is exactly the same as that of the shareholders (i.e. risk neutral), giving rise to the following utility function that is to maximize profits.

$$s.t. \quad b = y + z.$$

We yield the following solutions:

$$\tilde{y}_{manager} = b - \tilde{z}_{manager},$$

$$\tilde{z}_{manager} = \tilde{z} \cdot \lambda^{\frac{1}{\alpha-1}}.$$

(Proof F)

Proposition 4: When the compensation ratio takes the value of 1, we can easily see show the following

$$\tilde{z}_{manager,\lambda=1} = \tilde{z}$$

Proposition 5: We show that the gray project investments allocated by the manager increases in the compensation ratio, where:

$$\frac{dz}{d\lambda} > 0$$

(Proof G)

Proposition 4 shows that when the proportion of upside gain is equivalent to the downside loss, regardless of the magnitude of the proportion, the risk-neutral manager will engage in an optimal allocation of gray project investments. On the other hand, Proposition 5 shows that the allocation of gray project investments by risk-neutral managers increases in the compensation ratio. The implication is that the gray project investments increase in d_1 and decrease in d_2, leading to a suboptimal allocation of gray project investments and agency costs.

Taken together, our result shows that it is the relativity between the upside gain and downside loss that matters to risk-neutral managers. The magnitude of the upside gain to the manager is irrelevant if it is equivalent to the downside loss borne by the manager. Agency costs arise for risk-neutral managers when d_1 is different from d_2. Specifically, risk-neutral managers will overinvest in gray projects when d_1 is relatively larger than d_2.

Likewise, risk-neutral managers will underinvest in gray projects when d_1 is relatively smaller than d_2.

> Proposition 6: When managers are paid a fixed salary, managers have no incentive to maximize shareholders value.
>
> (Proof H)

Finally, our last result above shows that when managers are paid a fixed salary, the performance on the firm does not have any bearing on the manager's decision and the manager has no incentive to maximize shareholder value.

Our results in this section show that for a risk-neutral manager, agency costs can arise when managers are paid a fixed salary. Agency costs can also arise when the proportion of upside gain is different to the proportion of downside loss for the managers. The optimal compensation package for the firm is to have a variable compensation where the proportion of upside gain is identical to the proportion of downside loss for managers.

4. Implication of Agency Problem, Information Asymmetry and *Regbonds*

In section 3.2 and 3.3, we show that agency costs arise when there is a misalignment of risk preference and compensation mechanism, respectively. As discussed in section 2, firms seek to counteract the underinvestment problem brought about by risk averse managers with compensation mechanisms to better align the interests between shareholders and managers. Our model is able to explain this system of behavior as well.

We first assume changes in gray project investments arising from manager's risk preference is independent from the changes in gray project investments arising from the compensation ratio. This implies a multiplicative relationship where the following holds:

$$\tilde{z}_\eta^\lambda = \tilde{z} \cdot \left(h^{-\frac{\eta}{\alpha-1}} \right) \cdot \left(\lambda^{\frac{1}{\alpha-1}} \right).$$

> Proposition 7: A manager's optimal gray project investment tends to the firm's optimal gray project investment when the following relationship holds:
>
> $$\lambda = h^{\eta},$$
>
> where $h = y \cdot r_{g=0} + z \cdot r_{g>0}$.
>
> (Proof I)

Therefore, the key implication from our result is that when the manager is risk averse, the manager will underinvest in gray projects. Thus, a compensation ratio that is greater than 1 is required to reduce the underinvestment problem and bring it back to the firm's optimal level. Likewise, when the manager is risk seeking, the manager will overinvest in gray projects. Thus, a compensation ratio that is smaller than 1 is required to reduce the overinvestment problem and bring it back to the firm's optimal level. This result, ties in neatly with the literature documented in section 2.

In a bid to reduce the underinvestment in gray projects by risk averse managers, our model explains that the firms will strive to increase λ (by increasing d_1 and/or reducing d_2). Indeed, an increase in d_1 might explain the increasing popularity in equity-based compensation, granting of stock options upon hitting certain predetermined targets. We can see from Figure 9 that such a compensation mechanism is increasingly popular over the years.

Furthermore, to reduce d_2, we note that it is almost unheard of where managers are required to pay for the losses incurred by the firm. There are events when managers do get charged in court and are sentenced to a fine or jail penalty. However, these events are relatively rare and the impacts of such events to managers are further mitigated by director and officer (D&O) liability insurance where firms seek to reduce d_2.

This system is feasible when managers are indeed risk-averse agents, and having a large λ helps to mitigate the underinvestment problem and bring the investment allocation closer towards an optimal level. However, a problem arises when managers are risk-seeking agents, and having a similarly large λ worsens the overinvestment problem and pushes the investment allocation further away from the optimal level. The problem is

exacerbated when information is asymmetric and firms are unable to differentiate between the risk averse and risk seeking managers.

Some firms acknowledge this problem and have set up measures that increase d_2 by instituting clawback clauses (this forces managers to pay back the bonuses paid to them) and deferring compensation to a later date. These measures help reduce λ and mitigate the overinvestment problem by risk-seeking managers but in turn, it also worsens the underinvestment problem faced by risk-averse managers. Therefore, we identify that the root problem with the system is information asymmetry. The shareholders are unable to ex-ante differentiate between risk-averse managers and risk-seeking managers. They will only be able to identify the underlying risk preference of the managers ex-post, when the conviction event has already occurred. The information asymmetric problem makes it difficult for firms to take corrective and preventive measures to mitigate the overinvestment in gray projects by managers.

Admittedly in the literature, risk aversion is standard and usually taken as a given. However, in order to provide a more complete picture of the analysis, we selected different ranges of the relative risk aversion parameter. Furthermore, we suggest that in a real-world setting, a potential difficulty in the decision-making process by firm managers is due to the fact that some of them being extremely risk-seeking. Thus, being able to identify these managers will be useful for the firm to better manage their risk profile in terms of gray project investments.

4.1 Description of *Regbonds*

In the previous section, we note that information asymmetry between owners and managers make it difficult for shareholders to identify the risk-seeking and risk-averse managers. Therefore, in an environment with high λ, the underinvestment problem is mitigated in risk-averse managers while the overinvestment problem is worsened in risk-seeking managers. Assuming that both types of managers have the same budget constraint, this will lead to an overinvestment in gray projects at the firm-level.

In response, our paper proposes a novel solution: the *Regbonds*. The mechanism is straightforward, under which the shareholders will call for managers and employees to put up a portion of their own endowment into the *Regbonds*. This means that the managers and employees within the firm will put up a portion of their endowment (i.e. personal savings or a fixed portion of their monthly salary), and subscribe to the posting of *Regbonds* by the firm. After the subscription is completed, the *Regbonds* will be set aside and upon maturity, holders of the *Regbonds* will receive the principal and an interest payment. However, if a conviction event were to occur during the holding period of the <u>*Regbond*</u>, it will trigger a default and the monies from the *Regbonds* will be used to pay off the financial loss borne by the firm as a result of the conviction event. In our paper, we assume that *Regbonds* is quantitative in nature but in the real-world it needs not be purely financial and can take on more qualitative forms.

We further propose that subscription to the *Regbonds* by managers and employees are purely voluntary. The authors propose that it is indeed possible to have compulsory subscription of *Regbonds* but the authors do not find a compulsory scheme to be feasible for three reasons.

First, having a compulsory subscription from managers and employees seems like the firm is withholding the salary from their employees which the author believe is unethical and most likely illegal. Second, the underlying notion of having a *Regbond* is to allow risk-averse managers to signal to shareholders that they are not overinvesting in gray projects. If the subscription of *Regbonds* is made compulsory, both risk-averse and risk-seeking managers will have to subscribe to the bonds and shareholders will not be able to accurately identify the managers who are over-investing in gray projects. Third, an ex-ante compulsory subscription of *Regbond*s will result in an underinvestment in gray projects within the firm and does not solve the root issue of suboptimal gray project investments.

Furthermore, we propose two reasons that managers are indeed incentivized to voluntarily subscribe to *Regbonds* (and we show that these two reasons hold true based on our model in section 4.3). First, in an environment where information is asymmetric, good managers are often penalized for the overinvestment in gray projects that had been

undertaken by the bad managers. *Regbonds* provide these good managers with a mechanism to signal to the regulators that they are indeed good managers who have not overinvested in gray projects. This signaling mechanism ensures that the good managers are not penalized for the excessive gray project investments made by the bad managers, and thus we will see good managers voluntarily subscribing to *Regbonds*. Second, the coupon rate associated with the *Regbonds* provide an additional incentive for managers to subscribe to the *Regbonds*. Before subscribing to the *Regbonds*, managers will weigh the expected costs and benefits of subscription. We then show that the expected benefit from the coupon outweighs the cost of subscription for good managers. In turn, assuming managers are rational, the good managers will voluntarily subscribe to the *Regbonds*.

In addition, we note that some might view *Regbonds* as a simple variation of a deferred compensation. In the U.S., deferred compensation is defined as pension funds (i.e. 401(k)), retirement plans (i.e. can be set up by employers, insurers, trade unions or other institutions), and employee stock options. We agree that *Regbonds* can be seen as a form of deferred compensation but we propose that *Regbonds* fulfil a different purpose from traditional deferred compensation mechanism. We lay out three key differences between *Regbonds* and traditional forms of deferred compensation mechanism.

First, the default of *Regbonds* is triggered only in regulatory events (i.e. conviction). However, traditional deferred compensation mechanism can be defaulted on for multiple reasons that are non-regulatory events, such as not hitting of performance targets or firm's bankruptcy. This also means that in times of distress, the principal in *Regbonds* will not be used to pay off bankruptcy costs. Furthermore, in times of regulatory events, traditional deferred compensation mechanism tends to pay out to errant employees (Lewis, 2013). Thus, *Regbonds* are more suitable than traditional deferred compensation mechanism in allowing managers to internalize the external costs of their gray project investments. Coupled with the notion that the subscription of *Regbonds* is voluntary, this gives a signal that allows shareholders and regulators to identify the managers and firms that are overinvesting in gray projects, respectively. This signal cannot be produced by traditional deferred compensation mechanisms.

Second, it is feasible for the underlying assets of *Regbonds* to be held by the federal state, and the coupon payments can be paid out by the government as well, as the government benefits when the firm's managers internalize the external costs of their gray project investments, as documented in chapter 2. This is usually not the case for traditional deferred compensation mechanisms. This helps to ensure that the default of *Regbonds* is triggered only in regulatory events and the funds are kept safe from firm's distress.

Third, stock options in particular become increasingly valuable as employees invest more in gray projects as there is unlimited upside and a capped downside for managers. In contrary, *Regbonds* become more valuable as managers invest less in gray projects as the expected costs to the manager increase in gray project investments. This ties in neatly with the result of Proposition 5 that implies *Regbonds* help to counteract the effect brought about by stock options.

Therefore, we propose that these differences make *Regbonds* unique and ideal in mitigating overinvestments in gray projects within the firm compared to traditional forms of deferred compensation mechanisms. Furthermore, we do not view *Regbonds* as a substitute to traditional forms of deferred compensation mechanism but rather as a good complement. Specifically, we show in section 4.3 that a combination of stock options and *Regbonds* policies allow incentives to be aligned between shareholders and managers. This ensures that managers will allocate the firm-level optimal investments in gray projects. Furthermore, we propose that *Regbonds* is ex-ante in nature, and this differs from fines for misconduct (which is ex-post in nature). This allows firms and managers to internalize the cost of their decision making. Thus, we show that on the whole, *Regbonds* function as a mechanism that incentivizes firms and managers to do more *"good"*, and allow for improved monitoring that lead to overall value creation in the ecosystem.

4.2 Taking Corrective Action with *Regbonds*

In the prior section, we have discussed the underlying mechanism of *Regbonds*. In this section, we examine the subscription of *Regbonds* in an ex-post setting (while an ex-ante setting will be examined in the following section). This implies that the call for

subscription of *Regbonds* will be after the managers have completed their allocation of the investment budget for the firm. This means that managers will not be able to alter their allocation of gray project investments in this setting.

In order to keep our analysis mathematically tractable, we assume that the interest payment will always occur right before the default event. This assumption is required and means that the bondholders will always receive their interest payment, but stand to lose their principal if a default event does occur. Figure 3 plots the payoff timeline to manager under an ex-post *Regbonds* subscription.

[Place Figure 3 about here]

We continue to assume that there exists two managers within the firm, one is risk-averse (RA) while the other is risk-seeking (RS). Assuming that the information is asymmetric, shareholders are unable to differentiate between RA and RS managers. Shareholders will then optimally choose the same compensation mechanism for both managers, and this gives rise to the following:

$$\tilde{z}_i^\lambda = \tilde{z}_i \cdot \lambda^{\frac{1}{\alpha-1}} \quad , \qquad where \; i = RA, RS,$$

$$\tilde{z}_{RA}^\lambda < \tilde{z}_{RS}^\lambda,$$

where $\tilde{z}_{RA}$ and $\tilde{z}_{RS}$ are the gray project investments made by the risk-averse and risk-seeking manager when we assume that no agency issues arise from compensation mechanism, respectively, λ is the compensation mechanism applied similarly to both managers within the firm, and $\tilde{z}_{RA}^\lambda$ and $\tilde{z}_{RS}^\lambda$ are the gray project investments made by risk-averse and risk-seeking manager when we account for the compensation mechanism applied by the firm to both managers, respectively. Assuming that both managers have an equal proportion of the investment budget and they only have no information on investment allocation made by the other manager, this implies the gray project investments made at the firm-level, given by $\tilde{z}^\lambda$, is as follows:

$$\tilde{z}^\lambda = \frac{1}{2}\left(\tilde{z}_{RA}^\lambda + \tilde{z}_{RS}^\lambda\right).$$

Furthermore, as the payoffs have been priced in by the allocation of gray project investments, we only consider the marginal difference in the endowment of managers given by Figure 4 that plots the net endowment to manager under the ex-post setting.

[Place Figure 4 about here]

Proposition 8: A manager will choose to subscribe to *Regbonds iff* the following condition holds:

$$r_{reg} > g \cdot \left(\frac{\tilde{z}_i^\lambda}{z^*}\right)^\alpha \quad , \quad i = RA, RS$$

(Proof J)

Therefore, based on our model's result, a rational subscription to *Regbonds* by a RS manager is a sufficient condition for a RA manager to subscribe to *Regbonds*. However, the converse is not true. This implies that the following condition exists.

$$g \cdot v(\tilde{z}_{RA}^\lambda) < r_{reg} < g \cdot v(\tilde{z}_{RS}^\lambda).$$

When r_{reg} is within the range above, we yield an equilibrium where RA managers and RS managers will choose to and choose not to subscribe to *Regbonds*, respectively.

Next, we analyze if the firm will choose to post *Regbonds* with a r_{reg} that will make it reasonable for rational managers to subscribe to *Regbonds*. Figure 5 plots the cost to shareholders under an ex-post subscription of *Regbonds* setting.

[Place Figure 5 about here]

Proposition 9: Shareholders will choose to post *Regbonds iff* the following condition holds:

$$r_{reg} < g \cdot \left(\frac{\tilde{z}^\lambda}{z^*}\right)^\alpha$$

(Proof K)

Based on our prior assumption that each manager receives an equal amount of investment budget, this implies that the following relationship holds as well:

$$\left(\frac{\tilde{z}^{\lambda}_{RA}}{z^*}\right)^{\alpha} < \left(\frac{\tilde{z}^{\lambda}}{z^*}\right)^{\alpha} < \left(\frac{\tilde{z}^{\lambda}_{RS}}{z^*}\right)^{\alpha}.$$

Taken together with our earlier results, we show that the shareholders will never post *Regbonds* at a r_{reg} that is feasible for RS managers to subscribe to *Regbonds*. However, there exists a feasible condition where the RA manager and shareholders will choose to subscribe and post *Regbonds,* respectively, given as follows:

$$\left(\frac{\tilde{z}^{\lambda}_{RA}}{z^*}\right)^{\alpha} < r_{reg} < \left(\frac{\tilde{z}^{\lambda}}{z^*}\right)^{\alpha}.$$

Proposition 10: Furthermore, we show that there exists an upper limit of gray project investments for a given r_{reg}, as follows:

$$\hat{z} = \frac{z^* \cdot r_{reg}^{\frac{1}{\alpha}}}{g},$$

(Proof L)

where $\hat{z}$ is the upper limit of gray project investments that a manager can make given that he or she chooses to subscribe to the *Regbonds* posted by the shareholders at r_{reg}.

Therefore, shareholders can choose a r_{reg} where the following holds:

$$\hat{z} = \tilde{z}.$$

This means that those managers that choose to subscribe to *Regbonds* at this r_{reg} did not overinvest in gray projects. As a result, those managers that did not subscribe to the *Regbonds* are signaling that they have an overinvestment in gray projects. Therefore, when a firm posts a *Regbond* with a specified r_{reg}, the firm will be able to calculate the upper limit of gray project investments allocated by the managers who voluntarily subscribed to the *Regbonds*. Hence, in a firm with N managers where the managers are ranked based on their risk preference from the most risk averse to the most risk seeking,

we see that the percentage of subscription increases as the interest payment on the *Regbonds* increases. From the shareholder's perspective, they will be able to accurately observe the managers who have chosen (or not) to subscribe to the *Regbonds*. Assuming that the firm will be able to continually post *Regbonds* at different levels of r_{reg}. The implication is that firms will be able to receive a signal about the underlying risk preference of the managers and their allocation of gray project investments. Given that the firm sets a r_{reg} where $\hat{z} = \tilde{z}$, the firm will be able to accurately identify the managers who did not subscribe to the *Regbonds* as having overinvested in gray projects. This allows shareholders to undertake corrective action against the gray project investments undertaken by these managers before the financial penalty event occurs. By gaining a better understanding of the level of overinvestments in gray projects by RS managers, shareholders will be able to take actions that mitigate or resolve the overinvestments.

However, we propose a potential limitation with subscription of *Regbonds* in an ex-post setting. As the allocation of gray project investments have been decided ex-ante and we assume that this allocation cannot be changed under the ex-post setting. This implies that shareholders are unable to directly resolve the overinvestment problem by changing the allocation of gray project investments. Despite its limitations, we propose that an ex-post subscription of *Regbonds* is still better than no subscription of *Regbonds*, as the former allows for some form of corrective action to be undertaken. In the following section, we present an ex-ante subscription of *Regbonds* and show that it is more beneficial than an ex-post subscription.

4.3 Taking Preventive Action with *Regbonds*

In the prior section, we have shown that an ex-post subscription of *Regbonds* will allow shareholders to identify the managers who overinvest in gray projects. This signal allows them to undertake corrective action. However, this section looks at an ex-ante subscription of *Regbonds*.

This implies that the call for subscription of *Regbonds* will be before the managers have completed their allocation of the investment budget for the firm. This means that

managers will be able to alter their allocation of gray project investments in this setting. Furthermore, shareholders are able to undertake preventive action against overinvestment in gray project investments as the signal is given before the allocation is completed. This is given by the set-up in Figure 6.

[Place Figure 6 about here]

We first compare the gray project allocation between a subscribing manager and a non-subscribing manager, given by $\tilde{z}_{i,S}^{\lambda}$ and $\tilde{z}_{i,NS}^{\lambda}$ respectively. A subscribing manager will lose his principal when a financial penalty event occurs (i.e. negative cashflows). This can be seen as an increase in d_2 by subscribing managers.

Proposition 11: We show that the following relationship holds:

$$\tilde{z}_{i,S}^{\lambda} < \tilde{z}_{i,NS}^{\lambda}$$

(Proof M)

Our result suggests that a subscribing manager internalizes the cost of gray project investments. This means that the optimal gray project investments made reduces when a manager chooses to subscribe, relative to the level of gray project investments made under no subscription. In a similar manner to section 4.2, this gives rise to the following payoff diagram in Figure 7.

[Place Figure 7 about here]

Proposition 12: A manager will choose to subscribe to *Regbonds* *iff* the following condition holds:

$$r_{reg} > g \cdot \left(\frac{\tilde{z}_{i,S}^{\lambda}}{z^*}\right)^{\alpha} \quad , \quad i = RA, RS$$

(Proof N)

Our result here illustrates an added benefit of having an ex-ante subscription relative to an ex-post subscription. In a firm with N managers where the managers are ranked based on their risk preference from the most risk averse to the most risk seeking, we see that the

subscription rate will be higher in an ex-ante subscription relative to an ex-post subscription. This result implies that in an ex-post subscription, managers will only be able to make a subscription decision based on their prior allocation of gray project investments. However, in an ex-ante subscription, managers will now be able to internalize the cost of gray project investments. This means that the marginal group of managers that would not have subscribed to *Regbonds* in the ex-post setting, would now have a lower $\tilde{z}_{i,S}^{\lambda}$. This marginal group of managers would now fulfil the condition in Proposition 12 and choose to subscribe to *Regbonds*. Furthermore, the firm can decide on a r_{reg} where only managers who did not overinvest in *Regbonds* will subscribe, given as follows:

$$r_{reg} = g \cdot \left(\frac{\tilde{z}}{z^*}\right)^{\alpha}.$$

This signal allows the firm to accurately identify the group of managers who overinvest in gray projects. In response, the firm can undertake preventive action to mitigate the overinvestments by this group of managers. We propose that a feasible and equitable preventive action that can be undertaken will be to reduce the compensation ratio for this group of managers by reducing d_1. Coupled with our earlier result, this reduces the optimal gray project investments and the reduction makes it optimal for a marginal group of managers to subscribe to *Regbonds*. Assuming that the shareholders are able to continuously change the compensation ratio of managers with no transaction costs, the firm will be able to repeat this procedure. They can repeat this procedure until all managers have subscribed to the *Regbonds* and this ensures that there is no overinvestment in gray projects within the firm.

This begets the question of an underinvestment problem that is also suboptimal for the shareholders. We show that both the underinvestment and overinvestment problem can be resolved with an added-step in the implementation of *Regbonds*. This added-step ensures that all managers will invest the optimal amount of gray projects within the firm.

The solution is straightforward, where the shareholders set a sufficiently high d_1 before posting *Regbonds*. With a sufficiently high d_1, we can see that all managers within the firm will overinvest in *Regbonds*. Once this has been achieved, the firm can move on to

posting *Regbonds* and repeat the procedure mentioned above. The added-step ensures that there are no underinvestment in gray project within the firm, while the *Regbonds* and subsequent steps ensure that there are no overinvestment in gray project within the firm. Taken together, the shareholders are able to ensure that all managers (regardless of their risk preference) will invest the optimal amount of gray projects for the firm. Therefore, we have shown that *Regbonds* help to align the incentives between shareholders and managers.

Finally, we define the condition required for the firm to post *Regbonds*. Figure 8 plots the costs to shareholders under an ex-ante subscription setting.

[Place Figure 8 about here]

Proposition 13: Assuming that the firm posts *Regbonds* at a r_{reg} to identify managers who overinvest in gray projects, we show that the firm will choose to post *Regbonds iff* the following condition holds:

$$\left(\frac{\tilde{z}^{\lambda}}{z^*}\right)^{\alpha} - \left(\frac{\tilde{z}}{z^*}\right)^{\alpha} > 0 \quad , \quad i = RA, RS$$

(Proof O)

Our result shows that it will be optimal for the firm to post *Regbonds* only if there is an overinvestment in gray projects at the firm-level. The result suggests that if there is a net underinvestment in gray projects within the firm, the interest payment for *Regbonds* will outweigh the potential savings from the reduction in overinvestments in gray projects.

This ties in neatly with our earlier method that can ensure an optimal firm-level gray project investments. Before the subscription of *Regbonds*, the firm can increase d_1 to ensure that no underinvestments in gray projects exist within the firm. This condition also makes it feasible for the firm to post *Regbonds*. Therefore, the firm can post *Regbonds* and repeat the procedure mentioned above to ensure that no overinvestments in gray projects exist within the firm. Taken together, our paper shows that an ex-ante subscription of *Regbonds* can align the incentives between shareholders and managers.

This allows all managers to allocate an amount of investments to gray projects that is optimal for the firm.

Furthermore, our model assumes that the agents seek to maximize their expected utility at each point in time with the information set available to them at that point in time. Specifically, we assume that these agents do not preempt subsequent actions that will be undertaken by other agents in an information asymmetric setting. In retrospect, it is feasible for risk-seeking managers to anticipate the corrective and/or preventive actions that will subsequently be undertaken against them. Thus, it is possible for these managers to attempt to behave like risk-averse managers by subscribing to the *Regbonds* to ensure continuity in their gray project investments. This goes beyond the scope of this paper but makes for an interesting follow-up paper. However, we briefly propose that the firm will also be able to benefit in such a scenario. This is because when the risk-seeking managers attempt to disguise themselves as risk-averse managers by subscribing to the *Regbonds* (although this does not allow the firm to take action on the overinvestments but given that the conviction event does take place), the *Regbonds* will be triggered to cover part of the financial loss that was to be borne by the shareholders. If we assume that the *Regbonds* subscription by the RS managers is equivalent to the costs of overinvestments by the same manager. This implies that the risk-seeking manager will be paying for their overinvestments in gray project with their subscription to the *Regbonds*. Hence, we propose that the system of *Regbonds* will be beneficial for the firm even if RS managers choose to disguise as RA managers by replicating the subscription undertaken by RA managers, simply because the replicated subscription will be costly for the RS managers.

Recall, in chapter 2, we discussed the potential negative side-effects of *Regbonds*. We then discussed the mitigating measures that could be applied to better account for these side-effects. Now, to provide a more well-rounded analysis, we also discuss three potential limitations of *Regbonds* in the real-world setting. The first potential limitation would be that in order to provide sufficient incentives for managers to voluntarily subscribe to *Regbonds*, a higher than usual coupon rate may be required and this can be costly to the company in the near-term. However, we suggest that if the *Regbonds* are indeed able to incentivize managers to internalize the external costs of their decision-making, the cost savings (from improved decision-making) will more than outweigh the near-term cost of

the higher than usual coupon rate. Furthermore, we show the conditions for this to hold true under Propositions 8 and 9 (in section 4.2) and Propositions 12 and 13 (in section 4.3).

The second potential limitation would be that the principal amount for a manager will likely be very small relative to the potential financial losses arising from gray project investments. This effect is exacerbated in large-scale companies, and calls the effectiveness of *Regbonds* into question. In response to this limitation, we propose that it is precisely that the principal amount is small that makes the *Regbonds* appealing. Despite the relatively small sum of the principal amount, it is still a substantial amount from the manager's perspective. Therefore, this relatively small amount of capital is able to incentivize the managers to undertake decisions that reduce their expected losses from gray project investments. Therefore, *Regbonds* is a mechanism that utilizes capital in an effective manner. The purpose of the principal is not that we expect it to be able to pay off the full financial losses arising from gray project investments, but rather we expect the principal to better align the incentives between managers and the firm. We see some similarities in the context of stock options compensation package for managers. The amount of compensation given to the manager is considered small when compared to the amount of growth and earnings that the firm enjoys. Despite the relatively smaller sum of the compensation, the amount is considered substantial by the manager and this incentivizes the manager to engage in better decision-making. Therefore, we do not expect the small principal amount of the *Regbonds* to impede the effectiveness of the *Regbonds*. On the contrary, this difference in magnitude actually makes the mechanism of *Regbonds* even more attractive. In addition, our argument here provides added support for the discussion of the first limitation. Even if the coupon rate might be higher than usual, but given the relatively smaller sum of the principal, the coupon amount paid out to the managers will be small as compared to the potential financial losses from gray projects.

The third potential limitation would be that a manager, having subscribed to the *Regbond*, can attempt to 'time' the subscription. Our model's timeline has accounted for this issue by assuming that observation of conviction event always occur before principal is returned to the manager. However, in the real-world, the manager could overinvest in

gray projects, still get the full principal (and coupon rate), and then leave the company before any sign of conviction. In response to this limitation, we propose that it is the model's insight that is valuable and may be applicable in other forms. The core issue that the chapter is targeting is about individual accountability and the ability to track decision-making by managers. Admittedly, the consequence can only be observable over time; however, the insights from our model provide justification for regulators to discipline managers in mechanisms similar to the *Regbonds*. For example, regulators around the world have consistently banned and removed licenses from erring managers for an extended time window for alleged wrong doing. [4] Our model sheds insights on the effectiveness of these ex-post mechanisms relative to the ex-ante mechanism proposed by *Regbonds* and illustrate the benefits of these ex-ante mechanisms. We propose that the insights from our model can help regulators and researchers design more effective mechanisms in curbing gray project investments by managers.

5. Empirical Analyses

This section provides some data analysis to show that the propositions within our paper ties in with empirical data. Due to *Regbonds* being a novel idea proposed within the paper and has not yet been implemented in practice, it is difficult to conduct analyses concerning *Regbonds*. Due to a lack of data, we are only able to show specific propositions to be true. Specifically, we test the implication from Proposition 5 where gray project investments increases in d_1.

We propose that a proxy for d_1 will be the amount of stock compensation. This is because the amount of stock compensation increases as the investment returns from the firm increase, and is exactly defined by d_1. However, it is difficult to ascertain the level of gray project investments made within the firm. Therefore, we identify that a firm with a high level of gray project investments has a higher likelihood of conviction. A conviction event

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[4] We document anecdotal evidence where regulators from different parts of the world (such as US, UK, China, and India) have applied an ex-post mechanism of banning erring managers (e.g. "UK director bans for fraud and theft rise", *The Telegraph*, 05/03/2009; "US court slaps trading ban on UK wealth manager at heart of FBI sting", *CityWire*, 07/30/2019; "China Bans Six Tied to $4.3 Billion Fraud From Securities Market" *Bloomberg*, 08/16/2019; "Fraud at listed firms: Stock market regulator Sebi to rein in erring auditors, valuers", *Firstpost*, 03/21/2018).

can be observed and we use a set of bail-out events as a proxy for the firms that were convicted. Therefore, our proxy for gray project investments is a bailout event by the government.

Data Description: Our data comes from two source. The bail-out data tracks 980 unique bailout events that occurred between 2007-2009. As the data only tracks the firm by their name and does not record the firm's *gvkey*, we do an eyeball check to match bailout firms with the firm name in Compustat. We were able to match 79 unique firms in Compustat that were bailed out by the government as recorded in ProPublica. We get firm-level fundamental data from Compustat between 1998-2009.[5]

We note that bail-out events are generally an indirect measure of gray project investments. However, in our sample of bail-out events that occurred between 2007-2009, a significant majority of these bailouts are targeted at financial institutions that were on the hook for the subprime mortgage crisis. While companies have been dealing in collateralized debt obligations (CDOs) for decades, the regulators only disciplined the associated misconduct of managers when the external costs of dealing in CDOs triggered a global financial crisis. We thus propose that dealing (i.e. underwriting and trading) in CDOs is a conventional type of gray project investment. Therefore, we propose that the firms who had been bailed out are most likely firms that had invested heavily in CDOs (i.e. defined as a type of gray project investment in our paper). Hence, we argue that in our setting, bail-out events that occurred between 2007-2009 provide a reasonable proxy for the level gray project investments undertaken by firms over the same period. Moving forward, we note that more direct measures (such as regulatory sanctions) of gray project investments could be used to validate our results in extension papers.

Table 1 shows the summary statistics of the data. Detailed variable descriptions are in Table A1. Panel A summarizes the data of our main sample on the firm ×year level, with a total of 85,625 observations containing 14,714 unique firms from 2001 to 2009.

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[5] This is because stock compensation data is only available in Compustat from 1998 and we stop in year 2009 as that is the last year of bailout data available from ProPublica. Furthermore, we drop observations after 2009 due to regulatory changes that changed the way stock compensation was structured and reported within firms. Refer to Figure 9 for more details.

Bailout_Dummy is the dummy variable for whether the firm was bailed out by the government in the year of observation, as documented by ProPublica. The mean is 0.00092 which means that 0.54% (i.e. 0.00092*85625/14714) of unique firms were bailed out by the government. Stock_Compensation is 8.04 which means that the average firm paid their executives US$8.04 million in stocks each year. For brevity, the remaining variables are control variables and the values are consistent to those in the literature. Furthermore, Panel B summarizes the data used in the full sample on the firm ×year level, with a total of 119,271 observations containing 17,750 unique firms from 1998 to 2009. We further document that values between Panel A and Panel B are consistent.

[Place Table 1 about here]

In Figure 9, we plot the number of unique firms that have stock compensation data available in Compustat. We note a spike in observations in year 2001 and a continued rise until year 2006. Thereafter, the firms that reported stock compensation began on a downward trend. This could be in response to a sharp slowdown of the U.S. economy in the fourth quarter of 2015 (Porter & Bajaj, 2006). Therefore, we further restrict our main sample to run from 2001-2009, we conduct additional tests with the full sample and continue to yield robust results.

[Place Figure 9 about here]

We consider the following linear model with firm- and year-fixed effects to mitigate concerns about omitted variables:

$$Bailout_{Dummy_{it}} = \alpha_0 + \alpha_i + \alpha_t + \beta \left(Stock_{Compensation} \right)_{i,t-j} + \gamma_i X_{it} + \varepsilon_{it} - (1),$$

where α_o, α_i and α_t represents the constant, firm i fixed-effect and year t fixed-effect, respectively. The normally distributed error term is denoted by ε_{it}. The dependent variable is if the firm was bailed out by the government in the year of observation. Our explanatory variables include stock compensation within the firm lagged by *j* years, which is also our key independent variable of interest, a *k*-vector of firm-level control variables and a set of firm- and year-fixed effects. We are primarily interested in the parameter β as it captures the prospective influence of the stock compensation on the firm's likelihood of being bailed out by the government. We also cluster our standard errors by firms.

We utilize an extensive list of control variables. We control for firm size using the natural log of asset and natural log of common equity (Brown & Caylor, 2009; Farre-Mensa & Ljungqvist, 2016), given by *Asset* and *Equity* respectively. We control for investment opportunities using *Capx/Sale* and *Depreciation/Sale* ratios (Fich & Shivdasani, 2006; Hoechle et al., 2012). We control for the firm's value using variations of the Tobin's Q, given by *TobinQ_1* and *TobinQ_2* (Deng, Kang, & Low, 2013; Masulis, Wang, & Xie, 2007). We also control for the firm's leverage using long-term leverage as well as total leverage (Farre-Mensa & Ljungqvist, 2016; Sanjai & Brian, 2008), given by *T_Leveraged* and *LT_Leveraged*, respectively. We run our regressions with variations within the control variables and document robust results. Detailed variable definitions are given in Table A1.

We report our results in Table 2. In Panel A, our key independent variable of interest is *Stock_Compensation$_{t-1}$* and it is significantly positive. For example, the coefficient of *Stock_Compensation$_{t-1}$* in column (1) is 0.0000383 significant at the 5% level. This means that when the firm's stock compensation in the prior year increases by US$1 million, the firm's likelihood of being bailed out in the current year increases by 4.15% (i.e. 0.0000383/0.0009226). Furthermore, we document consistent results across different specifications. We control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. We also control for *Asset*, *Capx/Sale*, *TobinQ_1* and *T_Leveraged* in odd columns and *Equity*, *Depreciation/Sale*, *TobinQ_2* and *LT_Leveraged* in even columns. The coefficient on *Stock_Compensation$_{t-1}$* is significantly positive in all columns, with a 5% significance level in columns (1)-(4) and 10% significance level in columns (5)-(6). In Panel B, our key independent variable of interest is *Stock_Compensation$_{t-2}$*. We continue to document that the coefficient of *Stock_Compensation$_{t-2}$* remains significantly positive in all columns. Furthermore, we repeat our analysis with the full sample (i.e. 1998-2009) and continue to yield consistent results in Table A2.

[Place Table 2 about here]

Furthermore, we repeat our analyses with only the control variables in Table 3 (i.e. we remove our key independent variable of interest). We show that most of our control

variables are significant across different specifications. For example, *Asset, TobinQ_1* and *T_Leveraged* are significant in the odd columns while *Equity* is significant in the even columns when we control for year and industry-fixed effects. However, when we compare these results with those of Table 2, we document that the explanatory power of these control variables is subsumed by our key independent variable. For example, In Table 3 column (1), *Asset* is significantly positive at the 1% level while *TobinQ_1* and *T_Leveraged* are significantly positive at the 5% level. However, when we include *Stock_Compensation$_{t-1}$* in column (1) of Table 2 Panel A, the explanatory power of the control variables disappears and is subsumed by the *Stock_Compensation$_{t-1}$* variable. Likewise, in column (1) of Table 2 Panel B, we document that the explanatory power of the control variables are subsumed by *Stock_Compensation$_{t-2}$*. We document similar findings across different columns. In addition, we document a significant improvement in the explanatory effects of the model in terms of the R^2 when we include our *Stock_Compensation* variable. For example, in columns (5) and (6) of Table 3, the R^2 is 0.001. However, in columns (5) and (6) of Table 2 Panel A, the R^2 improves by 0.022 and 0.043 respectively. We document similar results in Table 2 Panel B as well. We repeat our analysis with the full sample (i.e. 1998-2009) and continue to yield consistent results in Table A3.

In short, our results show that when the firm's stock compensation in the prior years are higher, their likelihood of being bailed out by the government increases contemporaneously. Furthermore, we show that our key independent variable of interest is a stronger predictor than other commonly used control variables.

[Place Table 3 about here]

Finally, we analyze how persistent the effect of a high *Stock_Compensation* in prior years is on contemporaneous bail out probability. In this analysis, we assign firms with *Bailout_Dummy* value of 1 for each of *t-1, t-2, …, t-j* years given that they were bailed out by the government in year *t*, where *j* takes the value of 2, 3 and 5 in Table 4 Panel A, Panel B and Panel C respectively. Furthermore, we drop all observations that were bailed out by the government in the year of the bail out. This analysis allows us to compare the level of *Stock_Compensation* in the *j* years prior to the bail out relative to the

Stock_Compensation of all other years of observations. We consider the following linear model with firm- and year-fixed effects to mitigate concerns about omitted variables:

$$Stock_{Compensation_{it}} = \alpha_0 + \alpha_i + \alpha_t + \beta \left(Bailout_{Dummy_j} \right)_{it} + \gamma_i X_{it} + \varepsilon_{it} - (2).$$

Table 4 reports the results. In Panel A, our key independent variable, *Stock_Compensation,* is significantly positive. For example, the coefficient of *Bailout_Dummy$_j$* in column (1) is 44.27 at the 1% significance level. This means that in the two consecutive years prior to a bail out by the government, the to-be-bailed-out firm's *Stock_Compensation* is US$44.27 million higher than all other firm×year observations. Given that the mean *Stock_Compensation* is US$8.04 million, this translates into an increase of 551% (i.e. 44.27/8.04).

Furthermore, we document consistent results across different specifications. We control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. We also control for *Asset, Capx/Sale, TobinQ_1* and *T_Leveraged* in odd columns and *Equity, Depreciation/Sale, TobinQ_2* and *LT_Leveraged* in even columns. The coefficient on *Bailout_Dummy* is significantly positive at the 1% level in columns (1)-(4) and at the 5% level in column (5). In Panel B and C, where *j* takes the value of 3 and 5 respectively, we continue to document that the coefficient of *Bailout_Dummy* remains significantly positive in most of the columns. Furthermore, we repeat our analysis with the full sample (i.e. 1998-2009) and continue to yield consistent results in Table A4.

[Place Table 4 about here]

Our results provide a straightforward positive correlation relationship between the firm's *Stock_Compensation* and her being bailed out by the government in subsequent years. We do not purport any causal effects between these two dimensions as that is not the key focus of the paper. However, we do control for multiple fixed-effects models to mitigate omitted variable bias by eliminating the level effects across firms and the macro time trend. Furthermore, our analysis focuses on the lagged *Stock_Compensation* instead of contemporaneous observations to mitigate biasness arising from reverse causality.

In short, our result shows that when the firm's *Stock_Compensation* increases, it is associated with an increase in conviction likelihood in subsequent years. Given that *Stock_Compensation* is a good proxy for d_1 and a government bailout event is a good proxy for gray project investments, our results lend credence to the various Propositions derived from our model as well as the validity of the model.

6. Conclusion

Our paper introduces agency problem into the gray project investments model. We show that incentives can be misaligned when managers have non-risk-neutral utilities. In addition, when the proportion of upside gain is different from that of downside loss, agency problems arise as well. In response to these agency problems, managers will engage in suboptimal behavior that leads to over or under investments in gray projects at the costs of shareholders. Our empirical analysis shows that firms with higher stock compensation are associated with a higher likelihood of being bailed out by the government. This ties in neatly with our proposition and lends credence to our model. Stock compensation can mitigate the underinvestment behavior by risk averse managers, but it can will worsen the overinvestment problem concerning risk seeking managers. This problem arises due to information asymmetry where shareholders are unable to determine the underlying risk preference of managers. Therefore, this paper uses *Regbonds* to help mitigate the agency problem.

Using a micro view, this paper shows that *Regbonds* can act as a signaling mechanism on the underlying investment behavior of managers. We show that under the ex-post and ex-ante *Regbonds* subscription setting, it allows shareholders to engage in corrective and preventive actions, respectively. This helps to bring the gray project investments by managers closer towards firm-level optimal. More interestingly, we show that if shareholders are able to continuously adjust compensation ratio and that decisions are made with no future expectations, *Regbonds* can ensure a perfect alignment of interests between shareholders and managers. This means that all managers will invest at the firm-level optimal gray project investments, or any level as required by the shareholders.

Taken together, chapter 1 provides a model that explains gray project investments behavior by firm under different settings; chapter 2 explains how *Regbonds* can mitigate aggregate gray project investments at the macro level by addressing information asymmetry issues; and this paper explains how *Regbonds* can align interests between shareholders and managers at the micro level, this helps to ensure gray project investments made by managers are at the level preferred by shareholders. The goal of these three papers is to shed light on firm behavior concerning gray project investments at both the macro and micro level, and potentially bring gray project investments around the world to a more socially optimal level.

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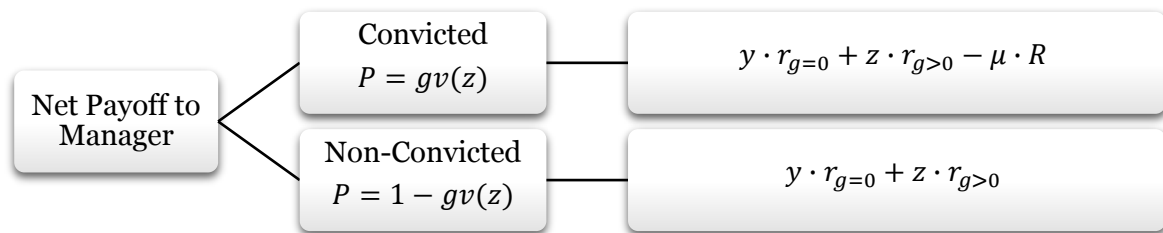
FIGURE 1. NET PAYOFF TO MANAGER (RISK-PREFERENCE)

$t = 0$
Managers decide on the
allocation of investment budget

$t = 1 - \Delta t$
Returns from investments
(Positive Cashflow)

$$d\left(y \cdot r_{g=0} + z \cdot r_{g>0}\right)$$

$t = 1$

$t = 1 + \Delta t$
Observation of financial
penalty event

Convicted
$P = gv(z)$

Non-Convicted
$P = 1 - gv(z)$

Financial Penalty
(Negative Cashflow)
$d(\mu R)$

0
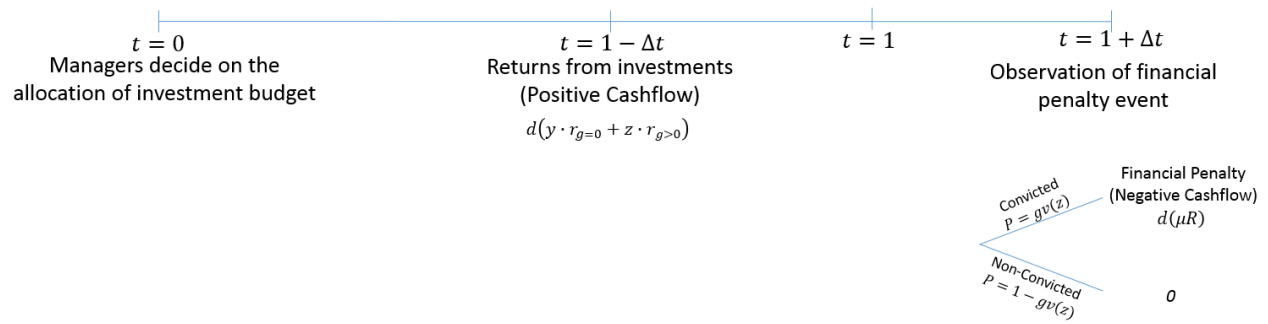
FIGURE 2. PAYOFF TIMELINE TO MANAGER (COMPENSATION-MECHANISM)

$t = 0$
Managers decide on the
allocation of investment budget

$t = 0 + \Delta t$
Ex-post issuance of
Regbonds

$t = 1 - \Delta t$
Interest payment from
Regbonds

$t = 1$

$t = 1 + \Delta t$
Observation of financial
penalty event
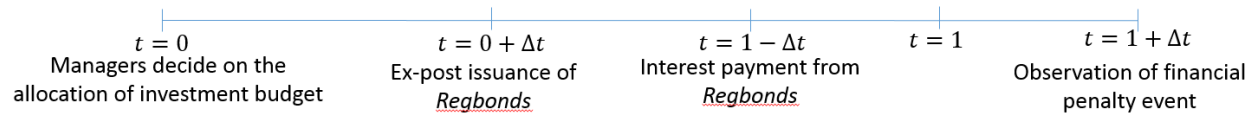
FIGURE 3. PAYOFF TIMELINE TO MANAGER (EX-POST *REGBONDS* SUBSCRIPTION)

Manager's Endowment branches to "With Regbonds" and "Without Regbonds".

With Regbonds:
- Convicted: $P = gv(\tilde{z}_i^\lambda)$ → $X \cdot (1 + r_{reg}) - X$
- Non-Convicted: $P = 1 - gv(\tilde{z}_i^\lambda)$ → $X \cdot (1 + r_{reg})$

Without Regbonds:
- Convicted: $P = gv(\tilde{z}_i^\lambda)$ → X
- Non-Convicted: $P = 1 - gv(\tilde{z}_i^\lambda)$ → X
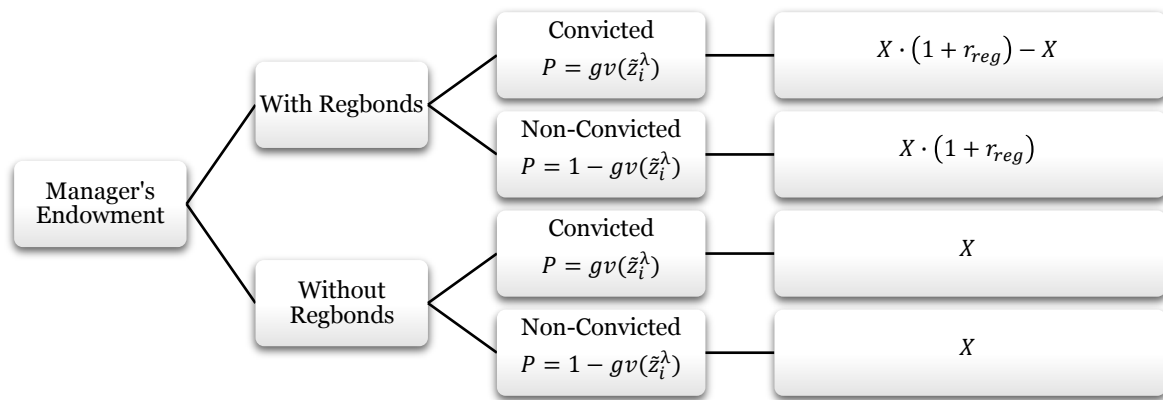
FIGURE 4. *REGBONDS*: NET ENDOWMENT TO MANAGER I (EX-POST)

FIGURE 4. *REGBONDS*: NET ENDOWMENT TO MANAGER I (EX-POST)

Shareholders' costs

With Regbonds

   Convicted
   $P = gv(\tilde{z}^{\lambda})$ — $X \cdot r_{reg} + (\mu R - X)$

   Non-Convicted
   $P = 1 - gv(\tilde{z}^{\lambda})$ — $X \cdot r_{reg}$

Without Regbonds

   Convicted
   $P = gv(\tilde{z}^{\lambda})$ — μR

   Non-Convicted
   $P = 1 - gv(\tilde{z}^{\lambda})$ — 0

FIGURE 5. *REGBONDS*: COST TO SHAREHOLDERS (EX-POST)

$t = 0 - \Delta t$ $t = 0$ $t = 1 - \Delta t$ $t = 1$ $t = 1 + \Delta t$

Ex-ante issuance of *Regbonds*   Managers decide on the allocation of investment budget   Interest payment from *Regbonds*   Observation of financial penalty event
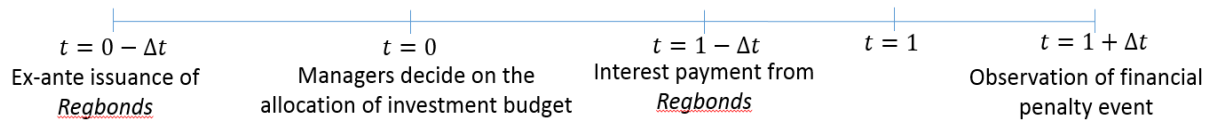
FIGURE 6. PAYOFF TIMELINE TO MANAGER (EX-ANTE *REGBONDS* SUBSCRIPTION)

Manager's Endowment

With Regbonds
- Convicted
  $$P = gv(\tilde{z}_{i,S}^{\lambda})$$
  $$X \cdot (1 + r_{reg}) - X$$
- Non-Convicted
  $$P = 1 - gv(\tilde{z}_{i,S}^{\lambda})$$
  $$X \cdot (1 + r_{reg})$$

Without Regbonds
- Convicted
  $$P = gv(\tilde{z}_{i,NS}^{\lambda})$$
  $$X$$
- Non-Convicted
  $$P = 1 - gv(\tilde{z}_{i,NS}^{\lambda})$$
  $$X$$
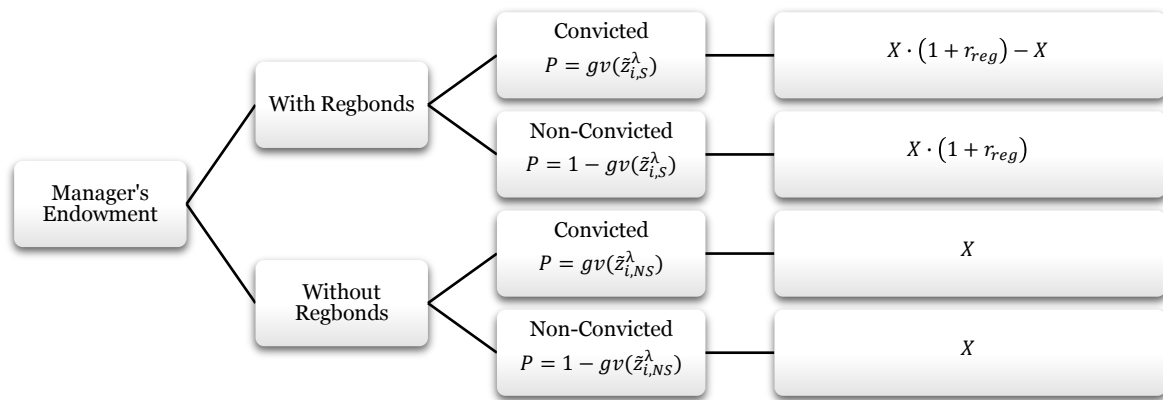
FIGURE 7. *REGBONDS*: NET ENDOWMENT TO MANAGER I (EX-ANTE)

Shareholders' costs

With Regbonds

Convicted
$P = gv(\tilde{z})$

$X \cdot r_{reg} + (\mu R - X)$

Non-Convicted
$P = 1 - gv(\tilde{z})$

$X \cdot r_{reg}$

Without Regbonds

Convicted
$P = gv(\tilde{z}^{\lambda})$

μR

Non-Convicted
$P = 1 - gv(\tilde{z}^{\lambda})$

0
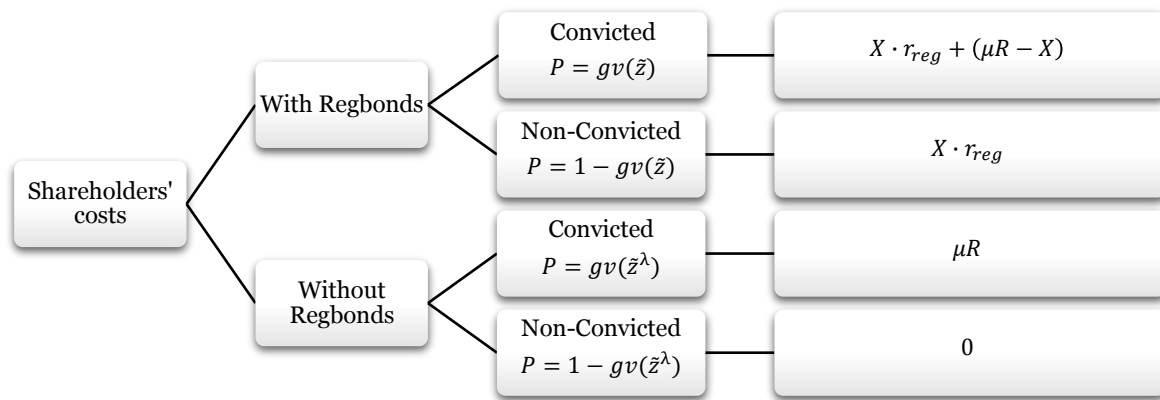
FIGURE 8. *REGBONDS*: COST TO SHAREHOLDERS (EX-ANTE)
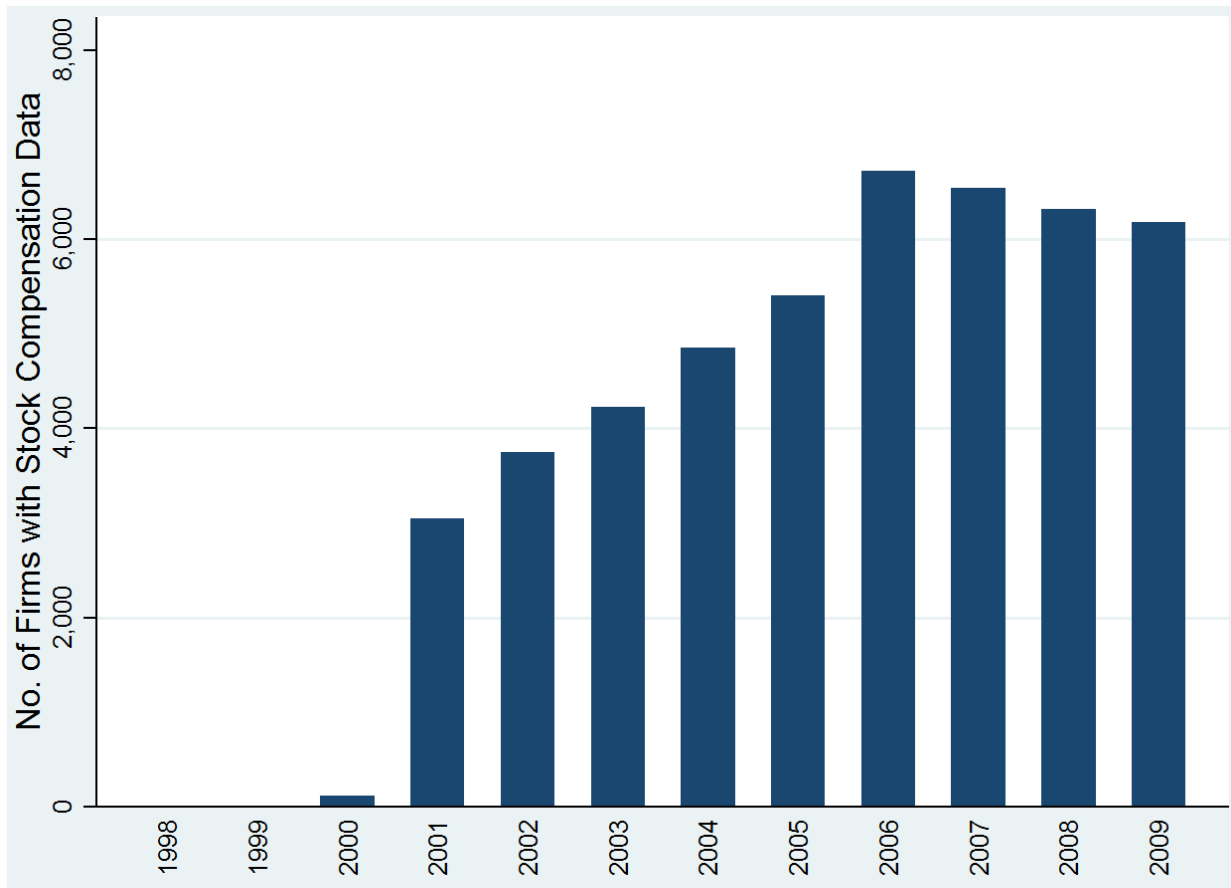
FIGURE 9. FIRMS WITH STOCK COMPENSATION DATA ACROSS TIME

This figure plots the number of firms that have Stock_Compensation data available in Compustat grouped by years in our sample period.

TABLE 1—SUMMARY STATISTICS

Variables	N	Mean	S.D.	Min	Median	Max
Panel A: Main Sample						
# unique firms	14714					
Bailout_Dummy	85625	0.000922628	0.03036095	0	0	1
Stock_Compensation	47049	8.036723714	24.49673786	-0.019	0.815	182
Asset	74285	5.315660386	3.025207586	-4.509768963	5.62558651	11.86637497
Capx/Sale	67003	0.138663369	0.437165389	0	0.031672254	3.529411793
TobinQ_1	64585	4.442456661	14.24203341	0.532581091	1.403578401	119.5249252
T_Leveraged	64014	0.253265865	0.386814393	0	0.127592914	2.595501184
Equity	63827	4.77877396	2.391944232	-1.864323735	4.820176601	10.24099541
Depreciation/Sale	68524	0.110223243	0.273839411	0	0.040967962	2.214285851
TobinQ_2	58341	4.982527339	16.65912671	0.511447966	1.463934064	140.318985
LT_Leveraged	56861	0.139017491	0.179317673	0	0.061821304	0.755707562
Panel B: Full Sample						
# unique firms	17750					
Bailout_Dummy	119271	0.000662357	0.025727883	0	0	1
Stock_Compensation	47182	8.01277591	24.42634095	-0.019	0.81	181.446
Asset	105291	5.189118182	2.932934864	-4.135104179	5.424315453	11.65745354
Capx/Sale	93536	0.159087837	0.505856084	0	0.035278568	4.092488289
TobinQ_1	91123	4.049880162	11.74039774	0.523376644	1.37823689	97.74766541
T_Leveraged	85925	0.250173244	0.361643689	0	0.129346609	2.30421567
Equity	90854	4.60486079	2.374588439	-1.897113323	4.62446785	10.04611492
Depreciation/Sale	97587	0.116086713	0.295233366	0	0.041807998	2.393196821
TobinQ_2	81617	4.509719202	13.56743897	0.498248309	1.447862029	112.4990845
LT_Leveraged	75303	0.144404289	0.184962498	0	0.063409515	0.761279404

Notes: This table describes the summary statistics of our sample. Panel A provides the summary statistics at the firm $\times$ year level for used in our main sample from 2001-2009. Panel B provides the summary statistics at the firm $\times$ year level for used in our full sample from 1998-2009. See Table A.1 for detailed variable definitions.

TABLE 2—BAILOUT DUMMY AND STOCK COMPENSATION (OLS)

Dependent Variable	1 Bailout	2 Bailout	3 Bailout	4 Bailout	5 Bailout	6 Bailout
Panel A. j=1						
Stock_Compensation$_{t-j}$	3.83e-05**	3.99e-05**	3.76e-05**	3.86e-05**	4.70e-05*	5.75e-05*
	(1.63e-05)	(1.86e-05)	(1.61e-05)	(1.85e-05)	(2.70e-05)	(3.33e-05)
Asset	7.84e-05		-3.80e-05		0.000241	
	(0.000130)		(0.000127)		(0.000542)	
Capx/Sale	-3.90e-08		2.40e-08		1.25e-08	
	(3.32e-08)		(4.08e-08)		(5.81e-08)	
TobinQ_1	6.15e-08		-1.60e-08		2.92e-08	
	(1.24e-07)		(1.05e-07)		(1.27e-07)	
T_Leveraged	2.96e-05		1.81e-06		1.79e-05	
	(2.70e-05)		(2.30e-05)		(3.58e-05)	
Equity		-0.000161		-0.000192		0.000151
		(0.000158)		(0.000161)		(0.000179)
Depreciation/Sale		-1.26e-07		8.06e-07*		-1.93e-07
		(3.02e-07)		(4.57e-07)		(2.97e-07)
TobinQ_2		-1.38e-06		-1.29e-06		4.17e-07
		(1.10e-06)		(9.21e-07)		(4.32e-07)
LT_Leveraged		0.000302		-0.000706		0.000796
		(0.000602)		(0.000789)		(0.000775)
Observations	30,099	25,055	30,099	25,055	30,099	25,055
R-squared					0.022	0.043
Number of Firms	7,194	6,385	7,194	6,385	7,194	6,385
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Dependent Variable	1 Bailout	2 Bailout	3 Bailout	4 Bailout	5 Bailout	6 Bailout
Panel B. *j*=2						
Stock_Compensation$_{t-j}$	3.92e-05**	3.76e-05*	3.79e-05**	3.56e-05*	4.25e-05*	4.32e-05*
	(1.80e-05)	(1.99e-05)	(1.70e-05)	(1.87e-05)	(2.20e-05)	(2.37e-05)
Asset	0.000181		4.84e-05		0.000503	
	(0.000142)		(0.000127)		(0.000704)	
Capx/Sale	-2.83e-08		3.71e-08		5.71e-08	
	(4.16e-08)		(4.80e-08)		(6.15e-08)	
TobinQ_1	1.47e-07		6.15e-08		7.58e-08	
	(1.40e-07)		(1.02e-07)		(1.47e-07)	
T_Leveraged	3.95e-05		1.70e-05		3.46e-05	
	(2.57e-05)		(2.06e-05)		(4.17e-05)	
Equity		-6.63e-05		-0.000100		0.000161
		(0.000154)		(0.000148)		(0.000175)
Depreciation/Sale		1.50e-07		8.54e-07**		3.77e-07
		(2.57e-07)		(4.20e-07)		(2.58e-07)
TobinQ_2		-7.24e-07		-7.36e-07		4.26e-07
		(8.23e-07)		(6.35e-07)		(3.92e-07)
LT_Leveraged		9.51e-05		-0.000981		0.00106
		(0.000683)		(0.000997)		(0.00112)
Observations	24,199	20,127	24,199	20,127	24,199	20,127
R-squared					0.019	0.026
Number of Firms	6,586	5,828	6,586	5,828	6,586	5,828
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data are restricted to the main sample of firms from 2001-2009. The dependent variable Bailout_Dummy is a dummy that takes the value of 1 if the firm is bailed out by the government in the year of observation, 0 otherwise. Our key explanatory variable of interest is Stock_Compensation within the firm lagged by j years, where j takes the value of 1 and 2 in Panel A and Panel B respectively. We also include a k-vector of firm-level control variables. Specifically, we control for Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

TABLE 3— BAILOUT DUMMY AND FIRM'S CHARACTERISTICS

	1	2	3	4	5	6
Dependent Variable	Bailout	Bailout	Bailout	Bailout	Bailout	Bailout
Asset	0.000208***		0.000170***		0.000107	
	(6.00e-05)		(4.94e-05)		(0.000262)	
Capx/Sale	-5.99e-08		-1.34e-08		1.36e-08	
	(3.79e-08)		(5.02e-08)		(5.86e-08)	
TobinQ_1	2.23e-07**		1.79e-07**		1.36e-08	
	(9.56e-08)		(7.87e-08)		(1.18e-07)	
T_Leveraged	1.58e-05**		1.35e-05**		2.82e-06	
	(7.12e-06)		(6.19e-06)		(5.58e-06)	
Equity		0.000119**		0.000107**		0.000104
		(4.88e-05)		(4.34e-05)		(0.000122)
Depreciation/Sale		1.93e-07		5.37e-07		-9.81e-08
		(2.92e-07)		(4.49e-07)		(1.93e-07)
TobinQ_2		6.98e-07		6.02e-07		2.76e-07
		(6.26e-07)		(6.24e-07)		(4.33e-07)
LT_Leveraged		-0.000213		-0.000284		0.000551
		(0.000254)		(0.000403)		(0.000378)
Observations	53,071	44,412	53,071	44,412	53,071	44,412
R-squared					0.001	0.001
Number of Firms	9,297	8,335	9,297	8,335	9,297	8,335
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data are restricted to the main sample of firms from 2001-2009. The dependent variable Bailout_Dummy is a dummy that takes the value of 1 if the firm is bailed out by the government in the year of observation, 0 otherwise. We only include a k-vector of firm-level control variables. Specifically, we have Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. This is essentially the same specification as Table 2 but without the key explanatory variable (i.e. Stock_Compensation$_{t-j}$). We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

TABLE 4—PERSISTENCY OF STOCK COMPENSATION EFFECT ON BAILOUT DUMMY

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel A. j=2						
Bailout_Dummy$_j$	44.27***	44.78***	43.36***	42.66***	34.62**	27.67
	(12.05)	(14.81)	(12.13)	(15.27)	(13.81)	(18.10)
Asset	3.543***		3.749***		2.139***	
	(0.138)		(0.146)		(0.191)	
Capx/Sale	0.000400		0.000367		0.000362	
	(0.000742)		(0.000730)		(0.000794)	
TobinQ_1	0.00165*		0.00173*		0.000557	
	(0.000879)		(0.000937)		(0.000458)	
T_Leveraged	0.0769***		0.0847***		0.0300***	
	(0.0273)		(0.0314)		(0.00937)	
Equity		3.741***		3.677***		1.698***
		(0.157)		(0.157)		(0.174)
Depreciation/Sale		0.00261		0.00104		0.000901
		(0.00359)		(0.00411)		(0.00352)
TobinQ_2		0.0112**		0.0106**		0.00282*
		(0.00491)		(0.00460)		(0.00162)
LT_Leveraged		-1.406		0.581		-0.875
		(0.863)		(0.949)		(1.177)
Observations	36,342	30,293	36,342	30,293	36,342	30,293
R-squared					0.094	0.095
Number of Firms	7,843	6,994	7,843	6,994	7,843	6,994
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel B. j=3						
Bailout_Dummy$_j$	44.62***	46.58***	43.68***	44.22**	34.97**	27.34
	(12.59)	(17.62)	(12.69)	(18.23)	(14.99)	(23.81)
Asset	3.534***		3.742***		2.131***	
	(0.138)		(0.146)		(0.189)	
Capx/Sale	0.000397		0.000364		0.000359	
	(0.000742)		(0.000730)		(0.000794)	
TobinQ_1	0.00165*		0.00173*		0.000554	
	(0.000877)		(0.000936)		(0.000457)	
T_Leveraged	0.0766***		0.0845***		0.0298***	
	(0.0272)		(0.0313)		(0.00928)	
Equity		3.733***		3.671***		1.694***
		(0.157)		(0.157)		(0.173)
Depreciation/Sale		0.00260		0.00104		0.000897
		(0.00357)		(0.00409)		(0.00351)
TobinQ_2		0.0112**		0.0106**		0.00282*
		(0.00491)		(0.00460)		(0.00162)
LT_Leveraged		-1.436*		0.554		-0.897
		(0.863)		(0.949)		(1.176)
Observations	36,342	30,293	36,342	30,293	36,342	30,293
R-squared					0.095	0.095
Number of Firms	7,843	6,994	7,843	6,994	7,843	6,994
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel C. _j_=5						
Bailout_Dummy$_j$	58.20***	70.72***	56.91***	68.13***	48.42***	56.56*
	(14.27)	(17.67)	(14.39)	(18.72)	(18.73)	(30.37)
Asset	3.513***		3.726***		2.128***	
	(0.137)		(0.145)		(0.190)	
Capx/Sale	0.000403		0.000368		0.000363	
	(0.000738)		(0.000726)		(0.000791)	
TobinQ_1	0.00164*		0.00172*		0.000553	
	(0.000873)		(0.000932)		(0.000457)	
T_Leveraged	0.0758***		0.0838***		0.0296***	
	(0.0268)		(0.0311)		(0.00921)	
Equity		3.704***		3.650***		1.685***
		(0.157)		(0.156)		(0.172)
Depreciation/Sale		0.00256		0.000984		0.000865
		(0.00359)		(0.00411)		(0.00351)
TobinQ_2		0.0111**		0.0106**		0.00280*
		(0.00489)		(0.00459)		(0.00162)
LT_Leveraged		-1.544*		0.466		-1.019
		(0.860)		(0.947)		(1.173)
Observations	36,342	30,293	36,342	30,293	36,342	30,293
R-squared					0.097	0.097
Number of Firms	7,843	6,994	7,843	6,994	7,843	6,994
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data are restricted to the main sample of firms from 2001-2009. The dependent variable is Stock_Compensation within the firm in the year of observation. The key independent variable of interest is Bailout_Dummy$_j$ a dummy that takes the value of 1 for each of t-1, t-2, …, t-j years given that the firm was bailed out by the government in year t, where j takes the value of 2, 3 and 5 in Panel A, Panel B and Panel C respectively, 0 otherwise. Furthermore, we drop all observations that were bailed out by the government in the year of the bail out. We also include a k-vector of firm-level control variables. Specifically, we control for Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix

Variables	Description
Bailout_Dummy	Dummy for whether the firm was bailed out by the government in the year of observation. Extracted from ProPublica.
Bailout_Dummy$_i$	Dummy that takes the value of 1 for each of t-1, t-2, …, t-j years given that the firm was bailed out in year t.
Stock_Compensation$_{t-j}$	Stock Compensation (i.e. *stkco*) retrieved from Compustat (in millions).
Asset	Natural log $(1 + at)$
Capx/Sale	Capital expenditures scaled by net sales
TobinQ_1	(Market value of assets *less* deferred taxes) scaled by total assets
T_Leveraged	Total liabilities scaled by beginning-period stockholders' equity
Equity	Compustat item *csho*prcc_f*
Depreciation/Sale	(Operating income before depreciation *less* Operating income after depreciation) scaled by net assets
TobinQ_2	(Total assets *less* Ordinary Equity + Market Equity *less* deferred taxes) scaled by total assets
LT_Leveraged	Total long-term debt scaled by beginning-period stockholders' equity

Notes: This table provides the detailed variable definitions of the variables used in our analysis.

TABLE A.2—BAILOUT DUMMY AND STOCK COMPENSATION (OLS) FULL SAMPLE ANALYSIS

Dependent Variable	1 Bailout	2 Bailout	3 Bailout	4 Bailout	5 Bailout	6 Bailout
Panel A. j=1						
Stock_Compensation$_{t-j}$	3.83e-05**	3.99e-05**	3.76e-05**	3.86e-05**	4.69e-05*	5.74e-05*
	(1.63e-05)	(1.86e-05)	(1.61e-05)	(1.85e-05)	(2.70e-05)	(3.33e-05)
Asset	7.83e-05		-3.80e-05		0.000239	
	(0.000130)		(0.000127)		(0.000538)	
Capx/Sale	-3.90e-08		2.41e-08		1.25e-08	
	(3.32e-08)		(4.08e-08)		(5.80e-08)	
TobinQ_1	6.13e-08		-1.60e-08		2.87e-08	
	(1.24e-07)		(1.05e-07)		(1.26e-07)	
T_Leveraged	2.95e-05		1.84e-06		1.77e-05	
	(2.70e-05)		(2.29e-05)		(3.55e-05)	
Equity		-0.000161		-0.000192		0.000149
		(0.000157)		(0.000161)		(0.000178)
Depreciation/Sale		-1.27e-07		8.04e-07*		-1.86e-07
		(3.03e-07)		(4.57e-07)		(2.96e-07)
TobinQ_2		-1.38e-06		-1.29e-06		4.14e-07
		(1.10e-06)		(9.21e-07)		(4.31e-07)
LT_Leveraged		0.000301		-0.000704		0.000787
		(0.000601)		(0.000789)		(0.000773)
Observations	30,153	25,099	30,153	25,099	30,153	25,099
R-squared					0.022	0.043
Number of Firms	7,205	6,396	7,205	6,396	7,205	6,396
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

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Dependent Variable	1 Bailout	2 Bailout	3 Bailout	4 Bailout	5 Bailout	6 Bailout
Panel B. $j=2$						
Stock_Compensation$_{t-j}$	3.92e-05**	3.76e-05*	3.79e-05**	3.56e-05*	4.25e-05*	4.32e-05*
	(1.80e-05)	(1.99e-05)	(1.70e-05)	(1.87e-05)	(2.20e-05)	(2.37e-05)
Asset	0.000181		4.80e-05		0.000497	
	(0.000141)		(0.000127)		(0.000698)	
Capx/Sale	-2.82e-08		3.72e-08		5.70e-08	
	(4.15e-08)		(4.79e-08)		(6.14e-08)	
TobinQ_1	1.47e-07		6.12e-08		7.48e-08	
	(1.39e-07)		(1.01e-07)		(1.46e-07)	
T_Leveraged	3.94e-05		1.70e-05		3.44e-05	
	(2.57e-05)		(2.05e-05)		(4.14e-05)	
Equity		-6.60e-05		-0.000100		0.000159
		(0.000154)		(0.000148)		(0.000174)
Depreciation/Sale		1.44e-07		8.51e-07**		3.67e-07
		(2.65e-07)		(4.20e-07)		(2.56e-07)
TobinQ_2		-7.23e-07		-7.37e-07		4.22e-07
		(8.21e-07)		(6.34e-07)		(3.90e-07)
LT_Leveraged		9.48e-05		-0.000976		0.00104
		(0.000680)		(0.000993)		(0.00110)
Observations	24,266	20,182	24,266	20,182	24,266	20,182
R-squared					0.019	0.026
Number of Firms	6,597	5,836	6,597	5,836	6,597	5,836
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data uses the full sample of firms from 1998-2009. The dependent variable Bailout_Dummy is a dummy that takes the value of 1 if the firm is bailed out by the government in the year of observation, 0 otherwise. Our key explanatory variable of interest is Stock_Compensation within the firm lagged by j years, where j takes the value of 1 and 2 in Panel A and Panel B respectively. We also include a k-vector of firm-level control variables. Specifically, we control for Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	1	2	3	4	5	6
Dependent Variable	Bailout	Bailout	Bailout	Bailout	Bailout	Bailout
Asset	0.000163***		0.000134***		8.95e-05	
	(4.71e-05)		(3.91e-05)		(0.000174)	
Capx/Sale	-3.02e-08		-5.60e-09		3.43e-09	
	(4.14e-08)		(4.53e-08)		(4.83e-08)	
TobinQ_1	1.81e-07**		1.46e-07**		1.56e-08	
	(7.74e-08)		(6.43e-08)		(9.19e-08)	
T_Leveraged	5.31e-06*		4.64e-06*		1.58e-06	
	(3.03e-06)		(2.74e-06)		(2.54e-06)	
Equity		9.05e-05**		8.18e-05**		9.00e-05
		(3.73e-05)		(3.32e-05)		(9.32e-05)
Depreciation/Sale		1.81e-07		4.71e-07		-9.05e-08
		(2.39e-07)		(3.57e-07)		(1.55e-07)
TobinQ_2		1.67e-07*		1.69e-07*		2.34e-07
		(9.26e-08)		(9.53e-08)		(2.03e-07)
LT_Leveraged		-0.000137		-0.000141		0.000444*
		(0.000174)		(0.000264)		(0.000257)
Observations	70,336	59,259	70,336	59,259	70,336	59,259
R-squared					0.001	0.001
Number of Firms	11,211	10,259	11,211	10,259	11,211	10,259
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data uses the full sample of firms from 1998-2009. The dependent variable Bailout_Dummy is a dummy that takes the value of 1 if the firm is bailed out by the government in the year of observation, 0 otherwise. We only include a k-vector of firm-level control variables. Specifically, we have Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. This is essentially the same specification as Table A.2 but without the key explanatory variable (i.e. Stock_Compensation$_{t-j}$). We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel A. j=2						
Bailout_Dummy$_j$	44.22***	44.74***	43.31***	42.63***	34.52**	27.54
	(12.00)	(14.74)	(12.09)	(15.20)	(13.77)	(18.02)
Asset	3.532***		3.736***		2.149***	
	(0.137)		(0.145)		(0.191)	
Capx/Sale	0.000401		0.000368		0.000362	
	(0.000742)		(0.000730)		(0.000793)	
TobinQ_1	0.00165*		0.00173*		0.000561	
	(0.000878)		(0.000936)		(0.000460)	
T_Leveraged	0.0767***		0.0845***		0.0302***	
	(0.0272)		(0.0313)		(0.00942)	
Equity		3.716***		3.651***		1.694***
		(0.157)		(0.157)		(0.174)
Depreciation/Sale		0.00256		0.00100		0.000843
		(0.00358)		(0.00411)		(0.00351)
TobinQ_2		0.0112**		0.0106**		0.00287*
		(0.00495)		(0.00464)		(0.00166)
LT_Leveraged		-1.407		0.567		-0.858
		(0.863)		(0.949)		(1.181)
Observations	36,397	30,336	36,397	30,336	36,397	30,336
R-squared					0.095	0.095
Number of Firms	7,851	6,999	7,851	6,999	7,851	6,999
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel B. j=3						
Bailout_Dummy$_j$	44.57***	46.58***	43.64***	44.22**	34.87**	27.23
	(12.54)	(17.55)	(12.65)	(18.17)	(14.94)	(23.76)
Asset	3.523***		3.729***		2.141***	
	(0.137)		(0.145)		(0.189)	
Capx/Sale	0.000398		0.000365		0.000359	
	(0.000742)		(0.000730)		(0.000793)	
TobinQ_1	0.00164*		0.00173*		0.000558	
	(0.000876)		(0.000934)		(0.000459)	
T_Leveraged	0.0764***		0.0842***		0.0300***	
	(0.0270)		(0.0311)		(0.00932)	
Equity		3.708***		3.645***		1.691***
		(0.157)		(0.157)		(0.173)
Depreciation/Sale		0.00256		0.000994		0.000838
		(0.00357)		(0.00410)		(0.00350)
TobinQ_2		0.0112**		0.0106**		0.00286*
		(0.00495)		(0.00464)		(0.00166)
LT_Leveraged		-1.437*		0.540		-0.879
		(0.862)		(0.949)		(1.181)
Observations	36,397	30,336	36,397	30,336	36,397	30,336
R-squared					0.095	0.095
Number of Firms	7,851	6,999	7,851	6,999	7,851	6,999
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Dependent Variable	1 Stock_Comp	2 Stock_Comp	3 Stock_Comp	4 Stock_Comp	5 Stock_Comp	6 Stock_Comp
Panel C. *j*=5						
Bailout_Dummy_j	58.13***	70.64***	56.85***	68.05***	48.30***	56.37*
	(14.20)	(17.58)	(14.32)	(18.62)	(18.66)	(30.29)
Asset	3.502***		3.713***		2.138***	
	(0.137)		(0.145)		(0.190)	
Capx/Sale	0.000404		0.000370		0.000363	
	(0.000738)		(0.000726)		(0.000791)	
TobinQ_1	0.00163*		0.00172*		0.000557	
	(0.000872)		(0.000931)		(0.000459)	
T_Leveraged	0.0756***		0.0836***		0.0297***	
	(0.0267)		(0.0309)		(0.00926)	
Equity		3.679***		3.624***		1.682***
		(0.157)		(0.157)		(0.171)
Depreciation/Sale		0.00252		0.000943		0.000807
		(0.00359)		(0.00411)		(0.00351)
TobinQ_2		0.0111**		0.0105**		0.00284*
		(0.00493)		(0.00463)		(0.00166)
LT_Leveraged		-1.544*		0.452		-1.001
		(0.860)		(0.947)		(1.177)
Observations	36,397	30,336	36,397	30,336	36,397	30,336
R-squared					0.097	0.098
Number of Firms	7,851	6,999	7,851	6,999	7,851	6,999
FirmFE	NO	NO	NO	NO	YES	YES
IndustryFE	NO	NO	YES	YES	NO	NO
YearFE	YES	YES	YES	YES	YES	YES
Cluster SE	Firm	Firm	Firm	Firm	Firm	Firm

Notes: This table presents the results of the cross-sectional regression. Data uses the full sample of firms from 1998-2009. The dependent variable is Stock_Compensation within the firm in the year of observation. The key independent variable of interest is Bailout_Dummy_j a dummy that takes the value of 1 for each of t-1, t-2, …, t-j years given that the firm was bailed out by the government in year t, where j takes the value of 2, 3 and 5 in Panel A, Panel B and Panel C respectively, 0 otherwise. Furthermore, we drop all observations that were bailed out by the government in the year of the bail out. We also include a k-vector of firm-level control variables. Specifically, we control for Asset, Capx/Sale, TobinQ_1 and T_Leveraged in odd columns and Equity, Depreciation/Sale, TobinQ_2 and LT_Leveraged in even columns. We also control for year-fixed, industry- and year-fixed, and firm- and year-fixed effects in columns (1)-(2), (3)-(4) and (5)-(6) respectively. Firm-clustered standard errors are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix 1

Proof A

Optimization problem is as follows:

$$\max_{z} \quad y \cdot \left(1 + r_{g=0}\right) + z \cdot \left(1 + r_{g>0}\right) - b - [g \cdot v(z) \cdot \mu \cdot R]$$

$$s.t. \quad b = y + z$$

Taking the first-order condition under constraint and setting the result to zero yields the following:

$$-\left(1 + r_{g=0}\right) + \left(1 + r_{g>0}\right) - \left[g \cdot \frac{\alpha}{z^*} \cdot \left(\frac{z}{z^*}\right)^{\alpha-1} \cdot R\right] = 0$$

$$\therefore \tilde{z} = \left[\frac{(z^*)^\alpha \cdot \left(r_{g>0} - r_{g=0}\right)}{\alpha \cdot g \cdot \mu \cdot R}\right]^{\frac{1}{\alpha-1}}$$

Proof B

$$E[U(w)] = [gv(z)] \cdot U(h - \mu R) + [1 - gv(z)] \cdot U(h)$$

Assuming that the utility function is additive,[6]

$$\Rightarrow E[U(w)] = U(h) - g \cdot v(z) \cdot \mu \cdot R$$

Taking first order condition and setting to zero,

$$\frac{dE[U(w)]}{dz} : U'(h) \cdot (r_{g>0} - r_{g=0}) = \alpha \cdot g \cdot z^{\alpha-1} \cdot \left(\frac{1}{z^*}\right)^\alpha \cdot \mu \cdot R$$

$$\therefore \tilde{z}_{manager} = \left[\frac{(z^*)^\alpha \cdot (r_{g>0} - r_{g=0}) \cdot U'(h)}{\alpha \cdot g \cdot \mu \cdot R}\right]^{\frac{1}{\alpha-1}}$$

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[6] Notice that our proof here does not make any specific assumption on the underlying definition of the utility function (i.e., we use a general utility function that is additive in nature).

Proof C

$$\because U(w) = \frac{(w)^{1-\eta}}{1-\eta}$$

$$\Rightarrow U'(h) = h^{-\eta}$$

$$\therefore \tilde{z}_{manager} = \tilde{z} \cdot h^{-\frac{\eta}{\alpha-1}}$$

<u>Proof D</u>

$$\because \tilde{z}_{manager} = \tilde{z} \cdot h^{-\frac{\eta}{\alpha-1}}$$

Taking first order condition,

$$\Rightarrow \frac{\partial \tilde{z}_{manager}}{\partial \eta} = -\frac{\tilde{z} \cdot \log(h) \cdot h^{-\frac{\eta}{\alpha-1}}}{\alpha - 1}$$

$$\therefore \frac{\partial \tilde{z}_{manager}}{\partial \eta} < 0$$

<u>Proof E</u>

$$\because U(w) = \begin{cases} \dfrac{1 - e^{-\kappa w}}{\kappa} & \kappa \neq 0 \\ w & \kappa = 0 \end{cases}$$

$$\Rightarrow U'(h) = \begin{cases} e^{-\kappa h} & \kappa \neq 0 \\ 1 & \kappa = 0 \end{cases}$$

$$\therefore \tilde{z}_{manager} = \begin{cases} \tilde{z} \cdot e^{-\frac{\kappa h}{\alpha - 1}} & \kappa \neq 0 \\ \tilde{z} & \kappa = 0 \end{cases}$$

$$\because \tilde{z}_{manager} = \begin{cases} \tilde{z} \cdot e^{-\frac{\kappa h}{\alpha - 1}} & \kappa \neq 0 \\ \tilde{z} & \kappa = 0 \end{cases}$$

Taking first order condition,

$$\Rightarrow \frac{\partial \tilde{z}_{manager}}{\partial \kappa} = \begin{cases} -\dfrac{h\tilde{z} \cdot e^{-\frac{\kappa h}{\alpha - 1}}}{\alpha - 1} & \kappa \neq 0 \\ 0 & \kappa = 0 \end{cases}$$

$$\therefore \frac{\partial \tilde{z}_{manager}}{\partial \kappa} \leq 0$$

<u>Proof F</u>

Recall the substitution:

$$\lambda = \frac{d_1}{d_2}$$

$$\Rightarrow E[U(w)] = \lambda \cdot d_2 \cdot \left(y r_{g=0} + z r_{g>0}\right) - d_2 \cdot [g v(z)] \cdot \mu R$$

Taking first order condition and setting to zero,

$$\frac{dE[U(w)]}{dz} : \lambda \cdot d_2 \cdot \left(r_{g>0} - r_{g=0}\right) = \alpha \cdot g \cdot z^{\alpha-1} \cdot \left(\frac{1}{z^*}\right)^{\alpha} \cdot d_2 \cdot \mu \cdot R$$

$$\Rightarrow \tilde{z}_{manager} = \left[\frac{(z^*)^{\alpha} \cdot \left(r_{g>0} - r_{g=0}\right) \cdot \lambda}{\alpha \cdot g \cdot \mu \cdot R}\right]^{\frac{1}{\alpha-1}}$$

$$\therefore \tilde{z}_{manager} = \tilde{z} \cdot \lambda^{\frac{1}{\alpha-1}}$$

<u>Proof G</u>

$$\because \tilde{z}_{manager} = \tilde{z} \cdot \lambda^{\frac{1}{\alpha-1}}$$

Taking first order condition,

$$\Rightarrow \frac{d\tilde{z}_{manager}}{d\lambda} = \frac{\tilde{z} \cdot \lambda^{\left(\frac{1}{\alpha-1}-1\right)}}{\alpha-1}$$

$$\therefore \frac{d\tilde{z}_{manager}}{d\lambda} > 0$$

Proof H

When managers are paid a fixed salary, this implies the following:

$$E[U(w)] = constant$$

Taking first order condition,

$$\frac{dE[U(w)]}{dz} = 0$$

This implies that the allocation of gray project investments has no bearing on the expected utility of the manager. Consequentially, managers will have no incentive to maximize shareholder value.

<u>Proof I</u>

Recall the following,

$$\tilde{z}_\eta^\lambda = \tilde{z} \cdot \left(h^{-\frac{\eta}{\alpha-1}} \right) \cdot \left(\lambda^{\frac{1}{\alpha-1}} \right)$$

In order for the following to hold,

$$\tilde{z} = \tilde{z}_\eta^\lambda$$

This implies that the following must hold,

$$\Rightarrow \left(h^{-\frac{\eta}{\alpha-1}} \right) \cdot \left(\lambda^{\frac{1}{\alpha-1}} \right) = 1$$

$$\therefore \lambda = h^\eta$$

Proof J

Manager i will choose to subscribe to *Regbonds* under an ex-post setting if the expected net endowment from subscription exceeds that without, given as follows:

$$E\big(Net\ Endowment_{with\ subscription}\big) > E\big(Net\ Endowment_{without\ subscription}\big)$$

$$\Rightarrow g \cdot \left(\frac{\tilde{z}_i^\lambda}{z^*}\right)^\alpha \cdot [X \cdot (1 + r_{reg}) - X] + \left(1 - g \cdot \left(\frac{\tilde{z}_i^\lambda}{z^*}\right)^\alpha\right) \cdot [X \cdot (1 + r_{reg})] > X$$

$$\therefore r_{reg} > g \cdot \left(\frac{\tilde{z}_i^\lambda}{z^*}\right)^\alpha$$

Proof K

Shareholders will choose to post *Regbonds* under an ex-post setting if the expected costs from posting are less than those without posting, given as follows:

$$E(Cost_{with\ posting}) > E(Cost_{without\ posting})$$

$$\Rightarrow g \cdot v(\tilde{z}^{\lambda}) \cdot [X \cdot r_{reg} + (\mu \cdot R - X)] + \left(1 - g \cdot v(\tilde{z}^{\lambda})\right) \cdot [X \cdot r_{reg}] > g \cdot v(\tilde{z}^{\lambda}) \cdot \mu \cdot R$$

$$\therefore r_{reg} < g \cdot \left(\frac{\tilde{z}^{\lambda}}{z^*}\right)^{\alpha}$$

<u>Proof L</u>

Recall that a manager will only subscribe when the following condition holds:

$$r_{reg} > g \cdot \left(\frac{\tilde{z}_i^\lambda}{z^*}\right)^\alpha$$

$$\Rightarrow \tilde{z}_i^\lambda < \frac{z^* \cdot r_{reg}^{\frac{1}{\alpha}}}{g}$$

Therefore, given that $\hat{z}$ denotes the upper limit of gray project investments that a manager can make given that he or she chooses to subscribe to *Regbonds*, it is easy to see that,

$$\hat{z} = \frac{z^* \cdot r_{reg}^{\frac{1}{\alpha}}}{g}$$

Proof M

$$\because d_{2,S} > d_{2,NS}$$

$$\Rightarrow \lambda_S < \lambda_{NS}$$

$$\Rightarrow \tilde{z} \cdot \left(h^{-\frac{\eta}{\alpha-1}}\right) \cdot \left(\lambda_S^{\frac{1}{\alpha-1}}\right) < \tilde{z} \cdot \left(h^{-\frac{\eta}{\alpha-1}}\right) \cdot \left(\lambda_{NS}^{\frac{1}{\alpha-1}}\right)$$

$$\therefore \tilde{z}_{i,S}^{\lambda} < \tilde{z}_{i,NS}^{\lambda}$$

<u>Proof N</u>

Manager i will choose to subscribe to *Regbonds* under an ex-ante setting if the expected net endowment from subscription exceeds that without, given as follows:

$$E\big(Net\ Endowment_{with\ subscription}\big) > E\big(Net\ Endowment_{without\ subscription}\big)$$

$$\Rightarrow g \cdot \left(\frac{\tilde{z}_{i,S}^{\lambda}}{z^*}\right)^{\alpha} \cdot \big[X \cdot (1 + r_{reg}) - X\big] + \left(1 - g \cdot \left(\frac{\tilde{z}_{i,S}^{\lambda}}{z^*}\right)^{\alpha}\right) \cdot \big[X \cdot (1 + r_{reg})\big] > X$$

$$\therefore r_{reg} > g \cdot \left(\frac{\tilde{z}_{i,S}^{\lambda}}{z^*}\right)^{\alpha}$$

Proof O

Shareholders will choose to post *Regbonds* under an ex-ante setting if the expected costs from posting are less than those without posting, given as follows:

$$E(Cost_{with\ posting}) > E(Cost_{without\ posting})$$

$$\Rightarrow g \cdot v(\tilde{z}) \cdot [X \cdot r_{reg} + (\mu \cdot R - X)] + (1 - g \cdot v(\tilde{z})) \cdot [X \cdot r_{reg}] > g \cdot v(\tilde{z}^\lambda) \cdot \mu \cdot R$$

$$\therefore \left(\frac{\tilde{z}^\lambda}{z^*}\right)^\alpha - \left(\frac{\tilde{z}}{z^*}\right)^\alpha > 0$$