ESSAYS ON FINANCIAL ECONOMICS

By

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ESSAYS ON FINANCIAL ECONOMICS

Abstract

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This dissertation contains three essays on financial economics. The first essay explores whether managerial inconsistent time preference leads to investment and financial distortions. Time-inconsistent CEOs are impatient – they want to experience rewards sooner and delay costs later. As a result, they repeatedly procrastinate some good investments and regularly preproperate borrowing and dividend payments, leading to underinvestment, over-borrowing and excessive dividend payments relative to the first-best. I first test this prediction via reduced-form regressions. I construct a proxy for time inconsistency based on managers' time preference revealed in their personal portfolio decisions. I find that firms with time-inconsistent managers significantly invest less, hold more debt and pay more dividends. I then formulate a dynamic investment model in which the value-maximizing manager has inconsistent time preference. Simulation results again confirm my argument: managers cut investments, hold more debt and make more dividend payments if they exhibit self-control problems.

The second essay exploits proprietary records of site visits in China and investigates how corporate site visits affect information asymmetry and whether this impact is influenced by the disclosure regulation. Starting from 2009, firms listed on Shenzhen Stock Exchange were mandated to disclose site visit information while firms listed on Shanghai Stock Exchange were

not required to do so. Using the adverse selection component of bid-ask spread and dispersion in analyst forecasts as proxies for information asymmetry, this paper finds that overall corporate site visits reduce information asymmetry. However, the reduction of information asymmetry is not significantly different between firms that are mandated to disclose and those that are not.

The third essay provides a dynamic minimum-variance hedge for firms in incomplete markets. By accounting for price transmission between the input and output prices, the model enables firms to minimize both input and output price fluctuations through a single tradable futures contract even in incomplete markets. The model conditions on the direction of price transmission between inputs and outputs, and on the availability of futures contracts. Using the problem of a hypothetical jet fuel producer as motivation, it is found that the two-sided model leads to a more effective hedge (more volatility reduction).

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To my mom for her endless love.

And to my husband who

always supports me.

CHAPTER 1 CORPORATE INVESTMENT, FINANCIAL POLICIES AND MANAGERIAL INCONSISTENT PREFERENCE

1. Introduction

In this paper, I attempt to explore whether managerial inconsistent time preference leads to distortions in firm decisions. In particular, I study the investment, financing and dividend policies of CEOs who have the propensity to obtain instant rewards and to avoid instant costs. I find that time-inconsistent CEOs cut investments, hold more debt and pay more dividends when compared to the time-consistent benchmark.

The standard corporate finance models assume that agents discount payoffs over time exponentially, i.e., they have consistent time preference. However, nearly all psychological experiments on time preferences suggest that this assumption is wrong (See, e.g. Ainslie, 1992; Loewenstein and Prelec, 1992). In fact, most people have self-control problems – they tend to avoid instant costs and to grab immediate rewards. For example, when presented a choice between earning $102 on June 1 versus $105 on June 15, if asked on April 1, nearly all people will prefer to earn $105 on June 15. But on June 1, facing the same choice, most people will choose to get the immediate $102 instead of waiting until June 15. In economics, this tendency to weight near-term payoffs higher are modeled as time-inconsistent, present-biased preferences (Pollak, 1968; Strotz, 1955).

Building on the extensive experimental evidence on present bias, I argue that one important link between personal characteristics of the CEO and corporate investment and financial strategies is managerial time preference. Different from managerial myopia which stems from the desire to mislead the market by boosting current accounting numbers (Jensen, 1986; Stein, 1988, 1989), the propensity to obtain instant rewards and to avoid immediate costs is a human tendency that could happen even if the manager has a long decision horizon and believes he is maximizing firm value. Time-inconsistent CEOs systematically weight well-being now higher than any future moment (Phelps and Pollak, 1968). Higher weight to immediate payoffs can mean that a present-biased manager tends to procrastinate the project when he should do it if the project involves immediate costs (O'Donoghue and Rabin, 1999). As a result, it is possible for a time-inconsistent CEO to delay some positive net present value (NPV) projects if he perceives it as too costly to invest now, even if it is optimal to do so. When future period arrives, he again procrastinates the value-creating project under the belief that the immediate costs are too high. As a result, if CEOs with self-control problems are not disciplined by corporate governance mechanisms, their bias for the present could lead them to repeatedly delay value-creating investment, resulting in underinvestment relative to the first-best.

Another effect of time inconsistency is the tendency to grab immediate rewards when it is optimal to wait. To the extent that borrowing from outside generates instant cash flows but has delayed interest payments and default costs, managers with present-biased preference tend to borrow more today because they underestimate the benefits of waiting (Meier and Sprenger, 2010).

Present-biased CEOs can augment self-control problems by repeatedly deciding to preproperate, leading to over-borrowing compared with time-consistent CEOs. Equity issuance, on the other hand, is not preferred by time-inconsistent managers as it involves instant issuance costs. The effect of self-control problems on dividend payment is similar: time-inconsistent executives will pay dividends instead of hoarding cash in cash-rich states, because dividend payment rewards shareholders immediately but interest is taxed. With each decision to preproperate payout, present-biased CEOs increase dividends paid to shareholders each period, resulting in excessive dividend payment in total.

To examine the effect of managerial inconsistent time preference on firm investment and financial behavior, I begin by reduced form regressions using a sample of U.S. firms from 1996 to 2016. I use CEO's personal portfolio decisions to elicit their attitude towards activities involving immediate rewards and construct a measure for managerial time inconsistency. The logic is as follows: executive options are an important part of CEO compensation. Despite that CEOs are prohibited to trade vested options or hedge their positions by short-selling company stock, risk-averse CEOs should exercise options early only if their moneyness is sufficiently high (Hall and Murphy, 2002; Lambert et al., 1991). If an executive persistently exercise the option earlier than the threshold suggested by previous literature (Hall and Murphy, 2002; Malmendier and Tate, 2005), I infer that he is impatient to grab immediate rewards.

My empirical results are as follows. I find that CEOs who are classified as present-biased simultaneously underinvest, hold less cash, have higher leverage levels and pay more dividends. These results are robust to controlling for standard firm financial characteristics, corporate governance, and managerial personal and compensation characteristics. To alleviate the endogeneity concerns of my analysis, I conduct additional tests and show that the effect of present bias on investment and financial decisions are not likely driven by alternative explanations like risk aversion, managerial myopia and negative inside information.

To further explore the effect of managerial inconsistent time preference on firm decisions, I formulate a dynamic structural model of optimal investment, financing and payout policies for a firm having an equity-maximizing but time-inconsistent manager[1]. The model I consider embeds corporate and dividend taxation, physical adjustment costs, and equity issuance cost. I analyze the implications of present-biased preference under two assumptions. First, the agents are "naïve" in that they assume that they are acting in a time-consistent manner (Akerlof, 1991). Second, agents are sophisticated in that they are full aware of their self-control problems (Laibson, 1997). To

[1] There are several reasons why a structural model is necessary to examine the effect of managerial inconsistent time preference. First, it is difficult to quantify the effect of managerial present bias because firms' hiring decisions and investment/financial policies are both endogenous: boards may take self-control into account at the time when they hire a CEO. It also lacks obvious instrumental variable for the manager's time preference ex-ante at the time when he\she makes investment/financial decisions. I use a backward looking present-bias measure based on CEOs' personal investment and I am able to alleviate some endogeneity concerns by adding control variables that are shown by prior studies to influence managerial myopia. However, it is still difficult to clearly distinguish present bias from myopia in a reduced-form regression as myopia could drive both early option exercise and underinvestment. Second, people have different beliefs about their future selves' preferences. They could be sophisticated and know exactly how their future selves will behave or they could be naïve and believe they are free of self-control problems. Reduced-form regressions could not distinguish different types of present-bias assumptions. Third, although reduced-form regressions can provide the directional effects of proxies for present bias on investment and financial decisions, they cannot, deliver the extent to which managerial inconsistent time preference influences firm value.

distinguish present bias from myopia, I also analyze firm investment and financial decisions if the manager has a short decision horizon.

I solve the model numerically and simulate firm investment, financing and dividend policies under different assumptions of time preference. The simulation result confirms that managerial inconsistent time preference leads to lower investment, more debt holding and higher dividend payment relative to the time-consistent benchmark. The extent of these investment and financial distortions depends on whether the present-biased manager is sophisticated or naïve. Specifically, I find that investment is less if the decision maker is naïve than if he is sophisticated. Because the naïve manager mistakenly believes that he will invest tomorrow, he repeatedly procrastinates some positive NPV projects because of their “high” immediate costs. The sophisticated decision maker, however, correctly foresees that he will delay some investment in the future. This self-awareness puts pressure on him to enforce self-control and increase investment today. As for financial decisions, sophisticated manager tends to borrow more and pay more dividends than does the naïve manager. This is consistent with the phycology prediction of present bias, as sophistication makes people more attracted by instant rewards (O'Donoghue and Rabin, 1999). Naiveté, on the other hand, motivates people to overestimate the benefits of waiting.

When comparing with myopic CEOs, I find that managers exhibiting self-control problems invest in a way that is less sensitive to productivity shocks. This is as expected if myopic CEOs exploit productivity shocks to boost current earnings. Different from present-biased managers who pay dividends instead of holding cash in cash-rich states, I find that myopic managers hold larger amounts of liquid asset. This is as expected if they attempt to exploit opportunities to increase short-term accounting numbers.

In drawing links to the extensive literature on corporate investment and financial decisions and on time-inconsistency I restrict myself here to work that is closest in spirit to my approach. This work is closely related to Riddick and Whited (2009) who analyze corporate saving propensity in a discrete investment dynamic model in which firms make investment, financing and distribution decisions. I extend their framework by embodying a time inconsistent parameter. I show that when the top decision maker of a firm has self-control problems of making time-inconsistent optimal choices, the firm underinvests, over-borrows and pays more dividends.

In a related paper, Grenadier and Wang (2007) examine the role of inconsistent time preference in the timing of investment by entrepreneurs in a dynamic real option model. They find that the time-inconsistent decision maker invests earlier than does an agent with standard time-consistent preference, and the extent of this hurry to invest is lower among naïve entrepreneurs. However, their analysis does not model how the entrepreneur finances the project. When considering financing costs, the decision to investment today may not be preferred by the present-biased decision maker as the immediate costs could be too high. My paper differs from theirs in that my model features simultaneous firm decisions on investment, financing and dividends strategies. After accounting for firm financing and dividend policies, simulation result confirms my argument that present bias induces managers to invest less compared to the level of investment that would be chosen by a time-consistent manager.

It is important to point out that managerial present-biased preference is not analogical to managerial myopia. In myopia models, the drive of short-termism is the executive's short horizon (Stein, 1988, 1989). When having a short horizon, managers only focuses on projects which generate positive reaction in the short-term. As a result, managers may abandon good investments in order to boost current earnings rather than the value of the firm. Different from myopia, managerial inconsistent time preference exists even in managers who have long decision horizons and who act in the interest of long-term firm value. My regression result that present bias has a negative effect on investment is robust to controlling for standard proxies for the tendency of myopia. Simulation result also confirms that present bias is not identical to myopia as they lead to different predictions on firm investment and financial behavior.

The paper extends a growing literature in corporate finance suggesting that the individual behavioral bias of the top decision maker within the firm can account for firm decisions (e.g. Malmendier and Tate, 2005). While amounted studies have shown the importance of time inconsistency for individual decision makings, less understood is whether a manager's bias for the present can affect the decision made at the organizational level. By highlighting the role of managerial present bias, my results indicate real consequences of managerial inconsistent time preference as it induces CEOs to cut investments, hold more debt, and make more dividend payments relative to the first-best. My research also extends the literature on behavioral finance by providing a flexible framework for recognizing time inconsistency as another behavioral bias in firm financial decisions.

This self-control based explanation for suboptimal firm investment and financial behavior has important policy implications. My findings suggest that a manager whose interests are perfectly aligned, who has a long decision horizon, and who does not face any information asymmetries may still make suboptimal investment and financial decisions if he lacks enough self-control to make optimal choices in a time-consistent manner. As a result, traditional provisions may not be sufficient to address managerial time inconsistency. Refined corporate governance structures, involving introducing commitment mechanisms to constrain present bias, may be important to achieve first-best corporate decisions.

The paper also contributes to the literature by merging two important strands of research: the structural corporate finance paradigm and the literature on inconsistent time preferences. Standard firm structural models assume an exponential discount function for managers, which is obviously at odds with the prominent stylized fact of inconsistent time preference suggested by psychology and economic studies. Meanwhile, given that the research on dynamic dividend payout is relatively rare, my findings extend the dynamic corporate finance literature by demonstrating that time-inconsistency may have significant implications on payout polices.

The following paper proceeds as follows. In Section 2, I motivate my self-control based story through reduced-form empirical analysis. In Section 3, I present a structure model for corporate investment and financial policies with a present-biased top decision maker. Section 4 describes the simulation and discusses the results. Section 5 concludes.

2. Motivating Empirical Analysis

In this section, I introduce my self-control based explanation for suboptimal investment and financial behavior through reduced-form regressions. CEOs exhibiting self-control problems are impatient – they want to grab rewards sooner but delay costs later. As a result, they procrastinate if projects incur instant costs (capital investment), and preproperate if actions bring immediate rewards (borrowing, dividend payout). These two manifestations of present-biased preference lead to distortions in firm investment and financial policies. Each period, the overestimation of instant costs makes present-biased managers to forgo some positive NPV projects they perceive to be too costly to invest today. Meanwhile, at each period, the overestimation of near-term payoffs induces excessive willingness to preproperate borrowing and dividend payments that involve immediate rewards. This bias for the present makes time-inconsistent CEOs to repeatedly delay value-creating investments, and to regularly increase debt holdings and dividend payments over time. These effects may be small for each period, but the incremental effect could be important. As a result, managerial present bias predicts underinvestment, over-borrowing and excessive dividend payout relative to the first-best. I thus obtain the following prediction:

Prediction 1: Present-biased CEOs invest less, borrow more, and pay more dividends, compared with time-consistent CEOs.

2.1 Measuring Present Bias

My measure of present bias is based on variations across CEOs in option exercise. Investors should wait to exercise options because of the non-negative value of the right to delay the stock purchase (Merton, 1973). Despite that CEOs are prohibited to trade vested options or hedge their positions by short-selling company stock, risk-averse CEOs should exercise options early only if the moneyness of vested options is sufficiently high (Hall and Murphy, 2002; Lambert et al., 1991). Malmendier and Tate (2005) calibrate the threshold for exercise to be 67%, using the Hall and Murphy (2002) model with a constant relative risk aversion (CRRA).

In my sample, I find that 77.13% of CEOs, however, persistently exercise vested options when they are less than 67% in-the-money. One interpretation of this persistent early exercise is present bias[2]. CEOs with self-control problems have the tendency to grab immediate rewards. They overestimate the benefits of early exercise, i.e., the instant gains and relief of risk exposure. As a result, present bias induces excessive willingness to exercise lowly in-the-money option when it is optimal to wait.

Based on these arguments, I construct my measure for present bias, *Present bias*, as CEOs who at least twice exercise vested options when their average moneyness is less than 67%.

[2] Other interpretations for exercising options early include risk aversion, myopia, and negative inside information. After relate present bias to financial decisions, I will discuss the implications of these alternatives on my results.

Execucomp does not have option-grant-specific prices, I therefore estimate the average moneyness of exercised options following prior literature (Campbell et al., 2011; Malmendier et al., 2011). Specifically, I estimated the total realizable value of the options following Core and Guay (2002). The average exercise price is estimated by subtracting the realizable value per option from the year-end stock price.

2.2 Data

I start with the Execucomp database for data on CEO compensation and characteristics for the period from 1996 to 2016. Information on directors is obtained from the RiskMetrics database. I collect data on accounting information from the Compustat database, and stoke return data from CRSP. The sample selection procedure is as follows: first, I exclude firms incorporated outside the United State. I then delete any CEO-firm-year observations with missing data, or with zero or negative total assets, the gross capital stock, or sales. I only include firms with at least two consecutive years of complete data. Finally, I omit regulated, financial and public service firms, of which the primary SIC is between 4900 and 4999, between 6000 and 6999, or greater than 9000. After winsorizing at the 2% and 98% level, I end up with an unbalanced panel of 4,976 firm-year observations.

Table 1.1 presents summary statistics of the data. For all sample firms, the mean *Present bias* is 0.7713, indicating that there is a substantial proportion of CEOs persistently exercise options before their moneyness reaches 67%. Other variables are not significant different between firms of which the CEO is classified as "present-biased" CEOs and firms that are not. Variables descriptions are summarized in Appendix 1.A.

Table 1.2 displays the correlations between variables. The correlation of the portfolio-based present-bias measure (*Present bias*) and *Investment* is negative and significant at the 5% level. It is also shown that *Present bias* is negatively correlated to *Cash*, and positively correlated to *Debt*. The correlations are of economic significance.

2.3 Investment, financial policy, and present bias

In this section, I use the portfolio-based present bias indicator to examine the effect of managerial inconsistent time preference on firm investment and financial behavior. The regression specification is as follows:

$$F_{it} = \beta_1 + \beta_2 P_{it} + X'_{it} B_3 + \varepsilon_{it} \tag{1.1}$$

where F_{it} is the investment and financial variables of interest, and P_{it} is the present-bias measure. I include year and industry dummies and cluster standard errors at the firm level.

The investment and financial policy variables I consider are: (1) *Investment*, defined as net capital expenditures scaled by total assets; (2) *Cash*, defined as the stock of cash over total assets; (3) *Debt*, defined as the total long-term debt to total assets; (4) *Net debt*, which is the difference between the stock of total long-term debt and cash, scaled by total assets; (5) *Payout,* defined as total cash distributions scaled by total assets.

X_{it} is a set of control variables containing firms' financial conditions, corporate governance, and CEO variables that are shown by prior studies to influence corporate investment and financial policies. The firm-specific financial variables included are firm size, market-to-book ratio and cash flow, which are relevant to the investment opportunities facing the firm and to its internal resources. I use efficient board size (1 if the board contains four to 12 members) as a proxy for corporate governance. At the executive level, I include CEO stock ownership and total number of vested stocks to control for the incentive effects of stock. These variables are relevant to the tendency of managerial myopia, which leads to reductions in long-run investment (Stein 1988, 1989; Bushee 1998; Edmans, Fang and Wang 2017). Low stock ownership motivates managers to boost accounting earnings rather than the firm value (Jensen, 1986). Myopia is also related to the decision horizon (Bizjak et al., 1993; Stein, 1988, 1989). I thus follow prior literature and include *Tenure* as a control for CEO short-termism (Antia et al., 2010).

Table 1.3 presents the results of Eq. (1.1) using the portfolio-based *Present Bias* as a proxy for managerial inconsistent time preference. The first column relates CEO's tendency to expedite option exercise to investment and demonstrates that *Present bias* has a negative coefficient that statistically significant at the 1% level (-0.0159, t-stat = -3.96). Thus, firms of which the CEO is impatient to exercise lowly in-the-money options systematically investment lower. This result is consistent with my self-control story that managers with present-biased preference tend to repeatedly procrastinate some value-creating projects that have immediate costs but delayed benefits, leading to underinvestment relative to the first-best.

In the next three columns, I examine the effect of present bias on leverage policies, including cash and debt holdings, as well as net debt stock. The coefficient on *Present Bias* for *Cash* is negative and significant, as predicted. The significant positive coefficient on *Debt* suggests that firms with present-biased managers tend to have higher leverage level. Accordingly, the coefficient on *Net Debt* is positive and significant at 5% level, suggesting that CEOs exhibiting self-control problems tend to hold more debt than cash. These findings are in accordance with Prediction 1 that present-biased CEOs are inclined to preproperate borrowing from outside because it involves immediate rewards but delayed costs. The last column reports the result for dividend payments. I find that firms with present-biased CEOs experience significantly higher dividend payout compared with firms with time-consistent CEOs – the coefficient on *Present bias* is 0.0136 and of highly statistical significance. This is as expected because holding cash incurs instant interest tax.

2.4 Discussion

The present-bias effect on investment and financial decisions may suffer endogeneity problems since there are many reasons for CEOs to expedite option exercise. These reasons may also influence firm investment and financial behavior. In this section, I discuss alternative reasons for CEOs to exercise options earlier than is suggested by rational models, and their relation to firm investment, financing and payout policies.

1. *Past Performance*. CEOs in firms with poor past stock performance may accelerate option exercise to avoid wealth loss. They may also invest less if pool past performance reflects poor

investment opportunities facing the firm. Meanwhile, if managerial wealth is highly sensitive to short-term stock price, pool past performance may motivate CEOs to forgo some positive NPV projects so as to inflate current stock price. The CEO may also be reluctant to issue equity and instead rely on debt financing, if pool past performance results in undervaluation of equity. To address this possibility, I add five lags of stock returns as additional controls in Eq. (1.1) and continue to find results that are qualitatively similar (not tabulated).

2. *CEO Risk Aversion.* Some CEOs may be more risk-aversion than assumed in the Malmendier and Tate (2005) calibration. These CEOs may both preproperate option exercise and underinvest, because it is possible for them to forgo projects with positive NPV but high risk. To distinguish the effect of present bias on investment and financial strategies from the impact of CEO risk aversion, I include volatility as an additional control. Lower volatility decreases option value and induces early exercise. Lower volatility is also related to increase in leverage, decreased cash holding and more dividend payments (Chen et al., 2014). My results are robust to adding volatility to controls in Eq. (3.1) (not tabulated).

3. *Managerial Myopia*. In myopia models (Stein, 1988, 1989), managers may cut investments in order increase short-term accounting earnings. Previous literature suggest that managerial myopia happens when managers hold little company stock (Jensen 1986) and lack long-term incentives. In Eq. (1.1), I control for the effect of managerial myopia on investment using *Tenure*. To further examine whether managerial myopia drives both underinvestment and early exercise, I

add *Long-term incentive plan* as an additional control for CEO short-termism (Antia et al., 2010). I also include whether the CEO also serves as a director as a control for the influence of CEOs. Adding these variables do not affect the estimated effect of early exercise materially (Panel A, Table 1.4).

4. *Other CEO Characteristics*. To test whether other CEO characteristics, such as age, and gender, lead to simultaneously underinvestment, over-borrowing, excessive dividend payout and early option exercise, I age and gender to the control variables in Eq. (1.1) . I find that my results are robust (Panel B, Table 1.4).

5. *Inside information*. Negative inside information can simultaneously cause early exercise and underinvestment. To test whether inside information contaminates the portfolio-based measure, I follow Malmendier and Tate (2005) and spilt the sample of CEOs who accelerate option exercise into early exercisers who always profit and early exercisers who at least once lose money. If the negative inside information drives both early exercise and underinvestment, then the portfolio-based present bias measure should only be significant for the "winning" group. Table 1.5 presents the results. As is shown, the coefficients on *Present bias* are significant for both subsamples. Thus, the underinvestment effect of inconsistent time preference is not likely driven by negative inside information[3].

[3] Results are also robust if I decompose my portfolio-based present-bias measure into two dummy variables. The first equals 1 if the CEO persistently exercises options earlier than the 67% threshold and is always better off by exercising the option early and investing in the market portfolio, and 0 otherwise. The second is 1 if the CEO persistently exercises options early and at least once loses money, and 0 otherwise.

3. Model

In this section, I consider a dynamic investment model with financing frictions. The model focuses on a representative firm that has a manager whose time preference could deviate from the standard time-consistency assumption. I first describe the economic environment facing the firm and then discuss alternative assumptions of time preferences. I compare investment, financing and distribution decisions under time-inconsistent preferences with the standard, benchmark case of time consistency. To distinguish managerial myopia from present-biased tendency, I compare the effect of managerial inconsistent time preference to results assuming a short decision horizon.

3.1 Economic Setup

A risk-neutral firm makes investment and financial decisions in discrete time $t \in \{1, 2, \ldots, T\}$. In any given period, the firm chooses (i) how much to investment; and (ii) how to finance the investment (internal or external funds). Production requires the input of capital stock k, and is subject to a productivity shock z. The profit function $\pi(k, z)$ is continuous, with $\pi(0, z) = 0$, $\pi_z(k, z) > 0$, $\pi_k(k, z) < 0$ and $\lim_{k\to\infty} \pi_k(k, z) = 0$. The shock z has bounded support $[\underline{z}, \overline{z}]$ and follows a first-order Markov process with transition probability $g(z', z)$, where a prime indicates a variable in the next period.

Investment, I is defined as

$$I \equiv k' - (1 - d)k \quad , \tag{1.2}$$

in which k' denotes the capital stock of next period and $d \in (0,1)$ is the capital depreciation rate.

As in Gomes (2001), I assume that k lies in the interval $\left[0,\bar{k}\right]$, in which $\bar{k}$ is defined as

$$(1-\tau_c)\pi\left(\bar{k},\bar{z}\right)-d\bar{k}=0 \ . \tag{1.3}$$

where τ_c is the corporate tax rate. Because $k>\bar{k}$ is not economically profitable, $\pi(k,z)$ is also bounded.

Capital investment has adjustment costs $A(k,k')$ (Cooper and Haltiwanger, 2006):

$$A(k,k')=\lambda_o k\Phi_i+\frac{\lambda_1}{2}\left(\frac{k'-(1-d)k}{k}\right)^2 k \ . \tag{1.4}$$

The capital adjustment costs encompass both fixed and smooth adjustment costs: the first term, $\lambda_o k\Phi_i$ captures the fixed adjustment costs, in which λ_o is a constant and $\Phi_i=1$ if investment $I\neq 0$, and 0 otherwise. The second term describes the smooth component and λ_1 is a constant.

As for financing, the firm may borrow, issue new equity or use its internal funds. For the purpose of brevity, I present the model with the stock of net cash p, which is defined as the difference between the stock of cash, c, and the stock of debt, b. It follows that $p>0$ indicates cash holdings of the firm while $p<0$ stands for the level of debt at each time point. The firm may hold cash that earns a taxable interest at a rate $r^r(1-\tau_c)$. Debt incurs taxable interest at the rate $r^c(1-\tau_c)$.

Without losing of generality, I follow Riddick and Whited (2009) to set the upper bound $\bar{p}$ to $\bar{k}/2$. As for debt, I assume an upper bound for debt $\bar{b}$, (i.e., a lower bound of net cash holdings $\underline{p}$), following the credit rationing literature which suggests that lenders will set a credit limit to borrowers because of the existence of adverse selection and moral hazard problems (See, e.g. Stiglitz and Weiss, 1981). Following DeAngelo et al. (2011), $\underline{p}$ is defined as $-\overline{p}$.

Equity issuance/distributions decisions are determined based on the principle that the sources and uses of funds are equal in each period. Let $e(k,k',p,p',z)$ denote the net equity/distributions. A value of $e(k,k',p,p',z)$ greater than zero indicates distributions to shareholders, and a value less than zero suggests new equity issuance. External equity financing incurs costs, $\phi(e(k,k',p,p',z))$ and $e(k,k',p,p',z)$ can be written as:

$$e(k,k',p,p',z) \equiv (1-\tau_c)\pi(k,z) + p - \frac{p'}{1+r(1-\tau_c)} - (k'-(1-d)k) - A(k,k'), \quad (1.5)$$

in which r equals r^r if $p' > 0$ and equals r^c if $p' < 0$. Following Hennessy and Whited (2007), $\phi(e(k,k',p,p',z))$ is modeled as linear-quadratic and weakly convex:

$$\begin{aligned} &\phi(e(k,k',p,p',z)) \equiv \Phi_e\left(\phi_0 - \phi_1 e(k,k',p,p',z) + \frac{1}{2}\phi_2 e(k,k',p,p',z)^2\right) \\ &\phi_i \geq 0, \quad i = 0,1,2 \end{aligned} \quad (1.6)$$

in which Φ_e equals 1 if $e(k,k',p,p',z) < 0$, and 0 otherwise.

3.2 Dynamic decisions

3.2.1 The time-consistent benchmark

As a benchmark, I consider the case in which the agent discounts payoffs exponentially. The decision maker chooses (k',p') to maximize the present value of future cash flows, which is discounted at the exponential discount rate δ. The Bellman equation is

$$V\left(k,p,z\right)=\max_{k',p'}\left\{e-\phi\left(e\right)-\Phi_d\tau_d e+\delta\int V\left(k',p',z'\right)dg\left(z',z\right)\right\} \qquad (1.7)$$

in which τ_d is the tax rate on distributions and Φ_d equals 1 if $e\left(k,k',p,p',z\right)>0$, and 0 otherwise.

The right-hand side of (1.7) specifies the decision faced by the firm. The first three terms represent the current equity distributions, abstracted from the issuance cost/dividend tax. The last term is equity continuation value. The existence of a unique solution for (1.7) is guaranteed by Theorem 9.6 in Stokey and Lucas (1989).

3.2.2 The inconsistent time preference

In my model, I adopt a convenient framework for present-biased preferences that has been widely used in the literature (e.g. Laibson, 1997; Phelps and Pollak, 1968). In particular, they capture the present bias with a two-parameter model in which the discount rate declines as payoff gets closer. Formally, let β represent a “ a bias for the present” and δ represent long-run, time-consistent discounting. For a decision maker at any time s, the discount function is equal to 1 for $t=s$ and to $\beta\delta^{t-s}$, for $t=s+1,s+2,\ldots$. When $\beta=1$, the discount function is identical to the time-consistent discounting. However, a β that is smaller than one will generate a bias for the present: the discount rate he applies to period τ in period τ is lower than he did in any period prior to period τ.

Another important question is whether the agent is aware of his future selves’ preference. Two assumptions are suggested by prior literature (Pollak, 1968; Strotz, 1955): first, the agent could be sophisticated, in the sense that they correctly anticipate that they act in a dynamically inconsistent manner. Second, the agent is naïve because he falsely believes that his future selves act in the interest of the current self.

3.2.3 The sophisticated decision maker

Consider the case of a sophisticated decision maker who chooses (k', p') each period to maximize the present value of future cash flows. Because of inconsistent time preference, he values the payoffs obtained from the decision made in future stages at only $\beta\delta$ of its future value. Let $W(k, p, z)$ denote the current value function, the current-period Bellman equation is

$$W(k', p', z') = \max_{k', p'} \left\{ e - \phi(e) - \Phi_d \tau_d e + \beta\delta \int V(k', p', z') dg(z', z) \right\} . \qquad (1.8)$$

As in (1.7), the first three terms of the right-hand of (1.8) represents the net equity distributions and $V(k, p, z)$ is the continuation value of equity. The only difference is that besides the exponential discount factor δ, the continuation value of equity is further discounted at the hyperbolical-induced parameter, β.

The problem presented by (1.8) could be solved by backward induction. Specifically, at the terminal period, the continuation function is the firm's total wealth:

$$V_{T+1}(k_{T+1}, p_{T+1}, z_{T+1}) = \pi(k_{T+1}, p_{T+1}) + k_{T+1} + p_{T+1} . \qquad (1.9)$$

Because the discount factor between any two future period is simply δ, the continuation payoff for other periods, $V(k, p, z)$, are defined recursively as

$$V(k', p', z') = e - \phi(e) - \Phi_d \tau_d e + \delta \int V(k', p', z') dg(z', z) . \qquad (1.10)$$

3.2.4 The naive decision maker

A naïve decision maker fails to realize that he will discount in a present-biased way in future periods. He wrongly believes that, starting from the next period, he will discount by δ between all periods. He will decide today, believing that he will choose from tomorrow forward by the exponential discount function. Thus, he mistakenly believes that the objective function faced by his future selves is

$$e_k - \phi(e_k) - \Phi_{d,k}\tau_d e_k + \delta \int V(k_{k+1}, b_{k+1}, z_{k+1})\, dg(z_{k+1}, z_k), \quad \forall k > t \qquad (1.11);$$

however, when he reaches the next date, he again reoptimizes the objective function with present-biased preference.

3.2.5 Myopic decision maker

In myopia theories (Stein 1988, 1989), the drive of myopic behavior is short planning horizon. To reflect the short-term focus of a myopia planner, I model the myopia discounting function as $\left\{1, \delta, \delta^2, \ldots, \delta^{t'}, (\beta\delta)^{t'+1}, (\beta\delta)^{t'+2}, \ldots\right\}$. Let t' be the last period of myopic planning horizon. The decision maker is patient with payoffs up to t', as he discount payoffs with long-run, time-consistent discounting. The myopic decision is impatient about payoffs that arrives after t'. I assume $t' = 5$ so that it matches the average vesting period of executive options (Edmans et al., 2013; Gopalan et al., 2014).

For a myopia decision maker, his objective is to maximize

$$\sum_{t=0}^{t'} \delta^t \left(e - \phi(e) - \Phi_d \tau_d e\right) + \sum_{t=t'+1}^{T} (\beta\delta)^t \left(e - \phi(e) - \Phi_d \tau_d e\right) . \qquad (1.12)$$

The first term in (1.12) represents the present value of payoffs in the short planning horizon, which is discounted exponentially at δ. The second term states the present value of long-run payoffs that are discounted by $\beta\delta$.

Figure 1 graphs the time-consistent discount function (assuming that $\delta = 0.995$), the present-biased discount function (with $\beta = 0.90$ and $\delta = 0.995$), and the myopia discount function (assuming that $\beta = 0.90$, $\delta = 0.995$ and $t' = 5$).

4. Simulation

This section solves the model numerically and compares its implications for different scenarios: (i) the time-consistent benchmark, (ii) the sophisticated time-inconsistent manager who correctly foresees his self-control problems, (iii) the naïve time-inconsistent manager who fails to realize his bias for the present, and (iv) the myopic manager.

4.1 Calibration

For production, the profit function has the form of $\pi(k,z) = zk^{\theta}$ in which $\theta \in (0,1)$ represents the curvature index of the profit function. I calibrate θ following Rotemberg and Woodford (1992) who assume a Cobb-Douglas production function and a demand function with constant elasticity. Their estimates suggest that $\theta \approx 0.75$.

As in Gomes (2001), I parameterize the shock z by using an AR(1) in logs,

$$\ln(z') = \rho \ln(z) + v' \tag{1.13}$$

in which v' has a truncated normal distribution $N\left(0,\sigma_v^2\right)$. I follow Tauchen (1986) and transform (1.13) into a discrete-state Markov chain, letting $\ln(z)$ have 20 points of support in $\left[-4\sigma_v\big/\sqrt{1-\rho^2},4\sigma_v\big/\sqrt{1-\rho^2}\right]$. Using the average estimates obtained by Hennessy and Whited (2007), I set the persistence of the shock, ρ, at 0.66 and the dispersion of the shock σ_v at 0.121.

For the equity financing cost function, $\phi\left(e\left(k,k',p,p',z\right)\right)$, my parameter choices for ϕ_0, ϕ_1, and ϕ_2 are from Hennessy and Whited (2007)'s estimates for larger firms. I set $\phi_0=0.389$, $\phi_1=0.053$, and $\phi_2=0.0002$. I follow Riddick and Whited (2009) to set the interest rate, r^r, equal to 4%. Similarly, the cost of capital, r^c, is set at 10%.

Following Cooper and Haltiwanger (2006), I parameterize the capital adjustment cost function by setting $\lambda_0=0.039$ and $\lambda_1=0.049$. The depreciation rate is set to equal 15% so that the model matches the depreciation ratio found in the data. Corporate tax rate is set at $\tau^c=0.30$ and dividend tax rate is set to equal $\tau^d=0.15$.

Finally, I follow Angeletos et al. (2001) and calibrate the discount functions by setting $\beta=0.75$ and $\delta=0.995$, as these parameter values roughly match experimentally measured discounting patterns. The length of planning horizon for myopia discounting function, t', is set at 5 so that it matches the average vesting period of executive options (Edmans et al., 2013; Gopalan et al., 2014). Table 1.6 summarizes parameters used in the calibration.

In the subsequent model simulation, the state space for capital stock, k, is

$$\left[\overline{k}\left(1-d\right)^{40},\ldots,\overline{k}\left(1-d\right)^{1/2},\overline{k}\right].$$

I let p have 20 equally spaced points in the interval $[-\overline{p}, \overline{p}]$, where $\overline{p} = \overline{k}/2$.

The model is solved via value function iteration using backward inductions in a finite horizon with $T = 1000$. The simulation starts with taking a random draw from the truncated conditional distribution of z', and then computing the value function $V(k, p, z)$ and the policy function $\{k', p'\} = h(k, p, z)$.

4.2 Results

Simulation results are summarized in Figure 2. The first plot is the CEO's decision on capital stock under different productivity shocks. As is expected, I find that compared with the time-consistent benchmark, managers who have a bias for the present always invest lower. Capital investment features immediate costs but delayed benefits. It follows that present-biased managers may repeatedly procrastinate some good investments that they believe to be too costly to invest now. The total investment thus is lower than the time-consistent benchmark. The extent of this underinvestment depends on whether the time-inconsistent manager correctly foresees his self-control problems. Specifically, I find that when the present-biased manager is not aware of his inconsistent time preference, he invests less than does if he knows he has a bias for the present. Intuitively, sophistication pushes the manager to avoid costly procrastination despite they are averse to incurring immediate costs. Comparing to the investment decision of a manager having a short horizon, time-inconsistent managers invest in a way that is less sensitive to productivity shocks. Since investment when productivity is high generates great return in the short run, myopic decision maker invests more (less) than hyperbolic decision makers when productivity shock is sufficiently high (low).

The second plot describes firm decisions on debt/cash holding. In most situations, a manager with present-biased preference and fully self-awareness tends to borrow more than does the time-consistent manager. Increases in debt holdings reward the company with immediate release of financial constraints but have delayed costs (interest payments and default costs). In this case, present-biased preferences induce sophisticated managers to accelerate debt issuance when it is optimal to wait. Meanwhile, managers with inconsistent time preference will payout dividends instead of hoarding cash because interest is taxed. If the time-inconsistent manager fails to foresee his inability to commit, the firm holds less debt but more cash compared to the sophisticated, present-biased cases. This is as expected since Naiveté motivates people to overestimate the benefits of waiting. The amount of liquid asset held by myopic decision maker is the highest among all types. This is consistent with the myopic assumption as myopic managers want to hold cash so as to exploit opportunities to increase earnings in short run.

The third plot presents the effect of time-inconsistency on firm equity issuance/net dividend policies. Different from the time-consistent manager who chooses to finance via equity issuance, time-inconsistent managers prefer to pay more dividends to shareholders. Similar to debt issuance, dividend payment has immediate rewards. Despite that equity issuance could ease financing constraints, it also involves instant issuance costs. The dividend payment by a sophisticated time-inconsistent manager is even higher than the naïve present-biased manager, as predicted since sophistication exacerbate the tendency to grab immediate rewards.

Collectively, simulation results suggest that compared to the time-consistent benchmark, the firm underinvests, over-borrows and pays more dividends if the CEO has sophisticated, present-biased preference; the firm invests less and makes higher dividend payments if the manager has time-inconsistent preference but is not aware of his self-control problems; and the firm holds more cash and invests less if the CEO is myopic.

5. Conclusion

In this paper, I link the managerial time inconsistency to firm investment, financing and dividend policies. My analysis consists of two main steps. First, I construct a measures of present-biased preference based on whether the CEO is impatient to grab immediate rewards when making private portfolio decisions. My empirical analysis confirms the time-inconsistency prediction that the propensity to grab instant rewards and to avoid immediate costs induces managers to invest less, borrow more and make more dividend payments. Additional tests suggest that these effects are not likely driven by alternative explanations like risk aversion, managerial myopia, negative inside information and other CEO characteristics.

Second, I build a dynamic investment model and compare the investment and financial policies when the top decision maker inside a firm (i) has time consistent preference, (ii) is present-biased and has full awareness of his self-control problems, (iii) is time-inconsistent but is not aware of his time inconsistency, and (iv) is myopic. Simulation results are consistent with my time-inconsistency prediction, as the managerial bias for the present leads to underinvestment, over-borrowing and excessive dividend payout compared to the first-best.

Time inconsistency have been widely shown to have significant implications on individual decisions, but whether the inconsistent time preference of the top decision maker would influence decisions made at the organizational level remains an open question. Building upon prominent results documented by experimental studies, I argue that managers could have the human tendency to put relatively higher weight to payoffs as payoffs come closer. By examining the effect of managerial inconsistent time preference on firm policies, my results suggest that present bias can have real effects on firm investment, financing and dividend policies.

Different from managerial myopia which has been widely-discussed in the literature, my findings suggest a new explanation for suboptimal investment and financial decisions. Unlike myopic behavior which is driven by the short decision horizon of executives (Stein, 1988, 1989), managerial inconsistent time preference can exist even with a manager who has a long horizon and behaves in an effort to increase long-term firm value. In fact, my regression results are robust to adding several controls for managerial myopia. Simulation results also demonstrate that managerial present bias influences firm decisions in a way different from myopia.

The results have implications for contract practice and organization design. It is suggested that agency costs could arise even when the manager does not face any information asymmetries and believes he is maximizing long-run firm value. As a result, standard incentive contracts are not likely to discipline these present-biased tendencies.

Appendix 1.A Variable Definitions

Variable	Definition
Investment	CAPXV minus SPPE, scaled by total assets, AT
Cash	Stock of cash, CHE, scaled by total assets, AT
Debt	Total long-term debt (DLTT plus DLC), scaled by total assets, AT
Net debt	The difference between long-term debt and cash stock ((DLTT+DLC) - CHE), scaled by total assets, AT
Payout	Total cash distributions (the sum of DVP, DVC and PRSTKC) over total assets, AT
Present bias	1 if the executive at least twice exercises an option when the option is less than 67% in-the-money.
Size	Market capitalization in Billion dollars.
Q	The market value of assets ((CSHO*PRCC_F) + (DLTT+DLC))to the book value of assets, AT
Cash flow	The sum of income before extraordinary items, IB and depreciation DP, divided by total assets, AT.
Stock Ownership	CEO stock ownership (as a percentage of total shares outstanding).
Vested Stocks	Total number of vested stocks (multiplied by 10 and normalized by total number of shares outstanding).
Efficient board size	1 if the number of directors on board is between four to twelve.
Tenure	Number of years as the CEO

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Table 1.1 Summary Statistics

	All Sample Firms			Firms if Present Bias = 1			Firms if Present Bias = 0		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Investment	4,976	0.1086	0.0719	3,838	0.1039	0.0672	1,138	0.1244	0.0838
Cash	4,976	0.1831	0.1650	3,838	0.1774	0.1603	1,138	0.2023	0.1787
Debt	4,976	0.1891	0.1719	3,838	0.1944	0.1696	1,138	0.1714	0.1782
Net debt	4,976	0.0063	0.2812	3,838	0.0172	0.2755	1,138	-0.0307	0.2970
Payout	4,976	0.0585	0.0759	3,838	0.0613	0.0751	1,138	0.0491	0.0778
Present bias	4,976	0.7713	0.4200	3,838	1.0000	0.0000	1,138	0.0000	0.0000
Size	4,976	8.8556	27.8015	3,838	10.1883	30.1332	1,138	4.3611	17.0743
Q	4,976	1.8444	1.2837	3,838	1.8123	1.1741	1,138	1.9527	1.5945
Cash flow	4,976	0.1027	0.0940	3,838	0.1042	0.0847	1,138	0.0977	0.1202
Stock Ownership	4,976	2.6601	5.0183	3,838	2.4100	4.8976	1,138	3.5037	5.3220
Vested Stocks	4,976	2.4833	4.9384	3,838	2.2344	4.7352	1,138	3.3227	5.4889
Efficient Board Size	4,976	0.9540	0.2096	3,838	0.9536	0.2103	1,138	0.9552	0.2070
Tenure	4,976	12.5376	8.1335	3,838	12.7473	8.2465	1,138	11.8304	7.7020

Data on executive characteristics and compensation from 1996 to 2016 are from Execucomp. Information on directors is obtained from the RiskMetrics database, accounting items are from Compustat, and stock return data come from CRSP. I exclude firms incorporated outside the U.S. and delete regulated, financial and public firms, of which the primary SIC is between 4900 and 4999, between 6000 and 6999, or greater than 9000. *Present bias* is an indicator for managerial inconsistent time preference based on preferences revealed in CEO's personal portfolio decisions. *Present bias* equals 1 if the executive at least twice exercise an option earlier than the 67% threshold. See Appendix A for variable definitions.

Table 1.2 Correlations

	Investment	Cash	Debt	Net debt	Payout	Present bias	Size
Investment	1.0000						
Cash	0.1883*	1.0000					
Debt	-0.1593*	-0.3947*	1.0000				
Net debt	-0.2071*	-0.8253*	0.8437*	1.0000			
Payout	0.0100	0.1376*	-0.0214	-0.0915*	1.0000		
Present bias	-0.1202*	-0.0633*	0.0563*	0.0715*	0.0679*	1.0000	
Size	0.0073	-0.0191	0.1067*	0.0765*	0.1310*	0.0880*	1.0000
Q	0.2915*	0.3582*	-0.1729*	-0.3124*	0.3831*	-0.0459*	0.1023*
Cash flow	0.1194*	0.0731*	-0.1598*	-0.1376*	0.3685*	0.0287*	0.1025*
Stock Ownership	0.0621*	0.1010*	-0.1223*	-0.1341*	-0.0075	-0.0915*	-0.0839*
Vested Stocks	0.0681*	0.1120*	-0.1250*	-0.1423*	-0.0058	-0.0926*	-0.0776*
Efficient Board Size	0.0446*	0.0684*	-0.1004*	-0.1020*	-0.0245	-0.0031	-0.2690*
Tenure	0.0391*	0.1004*	-0.0835*	-0.1104*	-0.0677*	0.0473*	-0.0879*

	Q	Cash flow	Stock Ownership	Vested Stocks	Efficient Board Size	Tenure
Q	1.0000					
Cash flow	0.4140*	1.0000				
Stock Ownership	0.0372*	-0.0158	1.0000			
Vested Stocks	0.0472*	-0.0108	0.9482*	1.0000		
Efficient Board Size	0.0226	-0.0294*	0.0545*	0.0522*	1.0000	
Tenure	0.0082	-0.0543*	0.4583*	0.4449*	0.0092	1.0000

This table presents the correlations of variables. * indicates statistical significance at the 5% level.

Table 1.3 Investment and Financial decisions and Portfolio-based Present Bias Measure

VARIABLES	Investment	Cash	Debt	Net Debt	Payout
Present bias	-0.0159***	-0.0226**	0.0178*	0.0406**	0.0136***
	(-3.96)	(-2.24)	(1.75)	(2.43)	(4.04)
Size	0.0001	-0.0001	0.0004**	0.0005***	0.0001**
	(0.73)	(-0.78)	(2.04)	(2.89)	(2.44)
Q	0.0153***	0.0456***	-0.0159***	-0.0609***	0.0163***
	(8.14)	(11.59)	(-4.76)	(-10.58)	(7.86)
Cash flow	0.0118	-0.1303***	-0.1775***	-0.0425	0.1711***
	(0.55)	(-3.01)	(-3.74)	(-0.57)	(6.23)
Stock Ownership	-0.0004	-0.0002	-0.0010	-0.0008	0.0004
	(-0.54)	(-0.15)	(-0.42)	(-0.28)	(0.61)
Vested Stocks	0.0005	0.0019	-0.0022	-0.0041	-0.0001
	(0.60)	(1.32)	(-0.99)	(-1.39)	(-0.12)
Efficient Board Size	0.0066	0.0132	-0.0317*	-0.0461**	-0.0064
	(1.11)	(1.12)	(-1.73)	(-2.07)	(-1.36)
Tenure	-0.0001	0.0011*	-0.0009	-0.0020**	-0.0005**
	(-0.32)	(1.77)	(-1.53)	(-1.98)	(-2.41)
Constant	0.1112***	-0.0395	0.3125***	0.3534***	0.0623
	(3.10)	(-1.03)	(4.90)	(4.19)	(0.94)
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Observations	4,976	4,976	4,976	4,976	4,976
R-squared	0.211	0.370	0.286	0.385	0.283

This table presents the regression result of investment and financial decisions on the portfolio-based present-bias measure. The dependent variables are net capital expenditures scaled by total assets (*Investment*), the stock of cash over total assets (*Cash*), the total long-term debt to total assets (*Debt*), the difference between total debt and the stock of cash, scaled by total assets (*Net debt*), and total cash distributions scaled by total assets (*Payout*). *Present bias* is an indicator for managerial inconsistent time preference based on preferences revealed by CEO's personal portfolio decisions. *Present bias* equals 1 if the CEO at least twice exercises an option earlier than the 67% threshold. Control variables are as described in the appendix. Year and industry dummies are included. Standard errors are clustered at firm level. T-statistics are reported in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 1.4 Alternative Explanations

Panel A: Controlling for other compensation and governance factors

	Investment	Cash	Debt	Net Debt	Payout
Present bias	-0.0160***	-0.0225**	0.0180*	0.0407**	0.0135***
	(-3.97)	(-2.22)	(1.76)	(2.43)	(4.00)
Long-term incentive plan	-0.0511	-0.0975	-0.0808	0.0167	-0.0867
	(-1.17)	(-1.56)	(-0.68)	(0.10)	(-0.90)
Executive as a director	0.0030	-0.0216	-0.0242	-0.0043	-0.0019
	(0.35)	(-0.74)	(-0.84)	(-0.09)	(-0.24)
Other Control Variables	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Observations	4,976	4,976	4,976	4,976	4,976
R-squared	0.211	0.370	0.287	0.385	0.283

Panel B: Controlling for other CEO characteristics

	Investment	Cash	Debt	Net Debt	Payout
Present bias	-0.0149***	-0.0224**	0.0176*	0.0401**	0.0136***
	(-3.72)	(-2.20)	(1.71)	(2.38)	(4.05)
Tenure	0.0003	0.0012*	-0.0010	-0.0022**	-0.0005**
	(1.19)	(1.89)	(-1.59)	(-2.11)	(-2.25)
Age	-0.0012***	-0.0003	0.0002	0.0005	-0.0001
	(-4.49)	(-0.42)	(0.37)	(0.47)	(-0.43)
Gender	-0.0033	-0.0026	0.0048	0.0070	0.0055
	(-0.38)	(-0.14)	(0.26)	(0.24)	(0.73)
Other Control Variables	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Observations	4,976	4,976	4,976	4,976	4,976
R-squared	0.222	0.370	0.286	0.385	0.283

Panel A presents the regression after adding the logarithm of one plus the number of long-term incentive plan and whether the executive serves as a director to Eq.(1.1). Panel B presents the result of a robust test using CEO age and gender as additional control variables. Dependent variables, *Present bias* and other control variables are as described in the appendix. Year and industry dummies are included for all firms. Standard errors are robust to heteroscedasticity and arbitrary within-firm serial correlation. T-statistics are in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 1.5 Test of Inside Information

	Early exercisers who always profit	Early exercisers who lose money
	Investment	Investment
Present bias	-0.0146***	-0.0236***
	(-3.59)	(-2.96)
Size	0.0001	-0.0002***
	(1.52)	(-2.73)
Q	0.0163***	0.0115***
	(7.28)	(4.44)
Cash flow	0.0165	-0.0052
	(0.68)	(-0.13)
Stock Ownership	-0.0003	-0.0010
	(-0.44)	(-0.80)
Vested Stocks	0.0003	0.0017
	(0.38)	(1.08)
Efficient Board Size	0.0059	0.0023
	(0.91)	(0.43)
Tenure	-0.0001	0.0002
	(-0.48)	(0.45)
Constant	0.1208***	0.0552**
	(3.35)	(2.02)
Year dummies	Yes	Yes
Industry dummies	Yes	Yes
Observations	3,728	1,248
R-squared	0.231	0.203

This table presents the sub-sample regression results using Eq. (1.1). I split the sample of CEOs who accelerate option exercise into early exercisers who always profit and early exercisers who at least once lose money. Standard errors are robust to heteroscedasticity and arbitrary within-firm serial correlation. T-statistics are in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 1.6 Calibration Parameters

Parameter	Benchmark Value	Empirical Restriction
Production		
θ	0.75	Curvature of the profit function
ρ	0.66	Persistence of the shock
σ_v	0.121	Standard deviation of the shock
Flotation Costs		
ϕ_0	0.389	Fixed Flotation Costs
ϕ_1	0.053	Unit Flotation Costs
ϕ_2	0.0002	Convex Flotation Costs
Capital Adjustment Costs		
λ_0	0.039	Fixed costs of adjustment
λ_1	0.049	Smoothed costs of adjustment
Discount Functions		
δ	0.995	Exponential discount rate
β	0.75	Hyperbolic-induced discount rate
t'	5	Length of planning horizon for myopia decision makers
Others		
r^r	0.04	Risk-free interest rate
r^c	0.10	Cost of capital
τ^c	0.30	Corporate tax rate
τ^d	0.15	Dividend tax rate
d	0.15	Depreciation rate

This table summarizes parameters used in calibration.

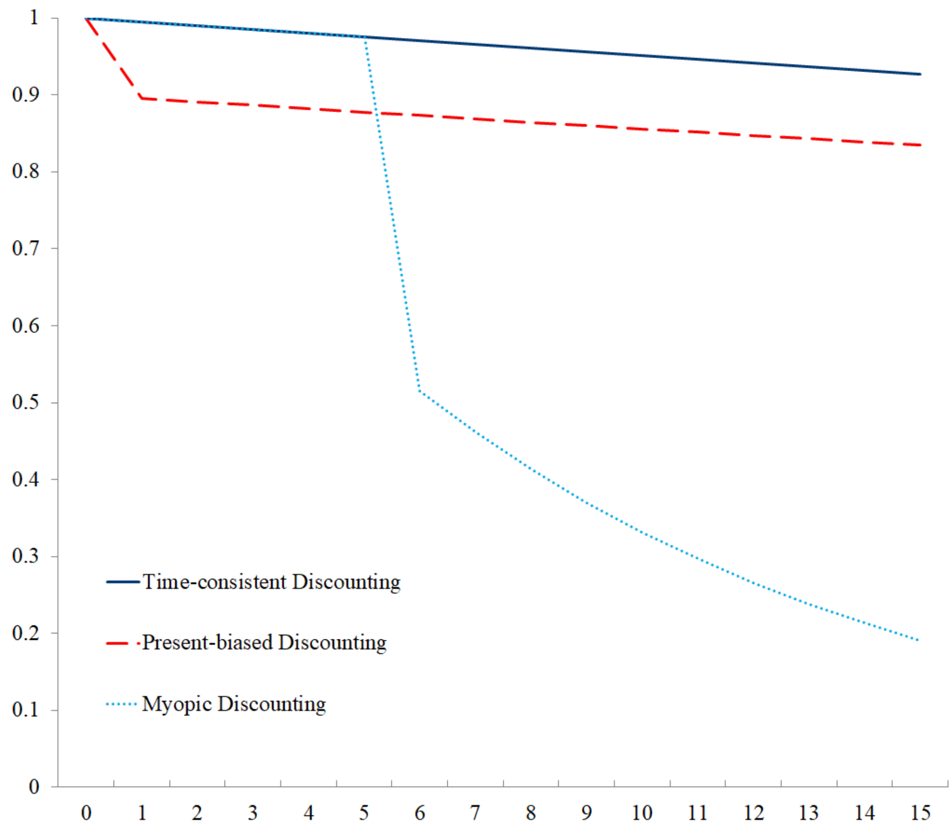

Figure 1.1 Discount Functions

This figure graphs the time-consistent discount function (assuming that $\delta = 0.995$), the present-biased discount function (with $\beta = 0.90$ and $\delta = 0.995$), and the myopic discount function (assuming that $\beta = 0.90$, $\delta = 0.995$ and $t' = 5$).

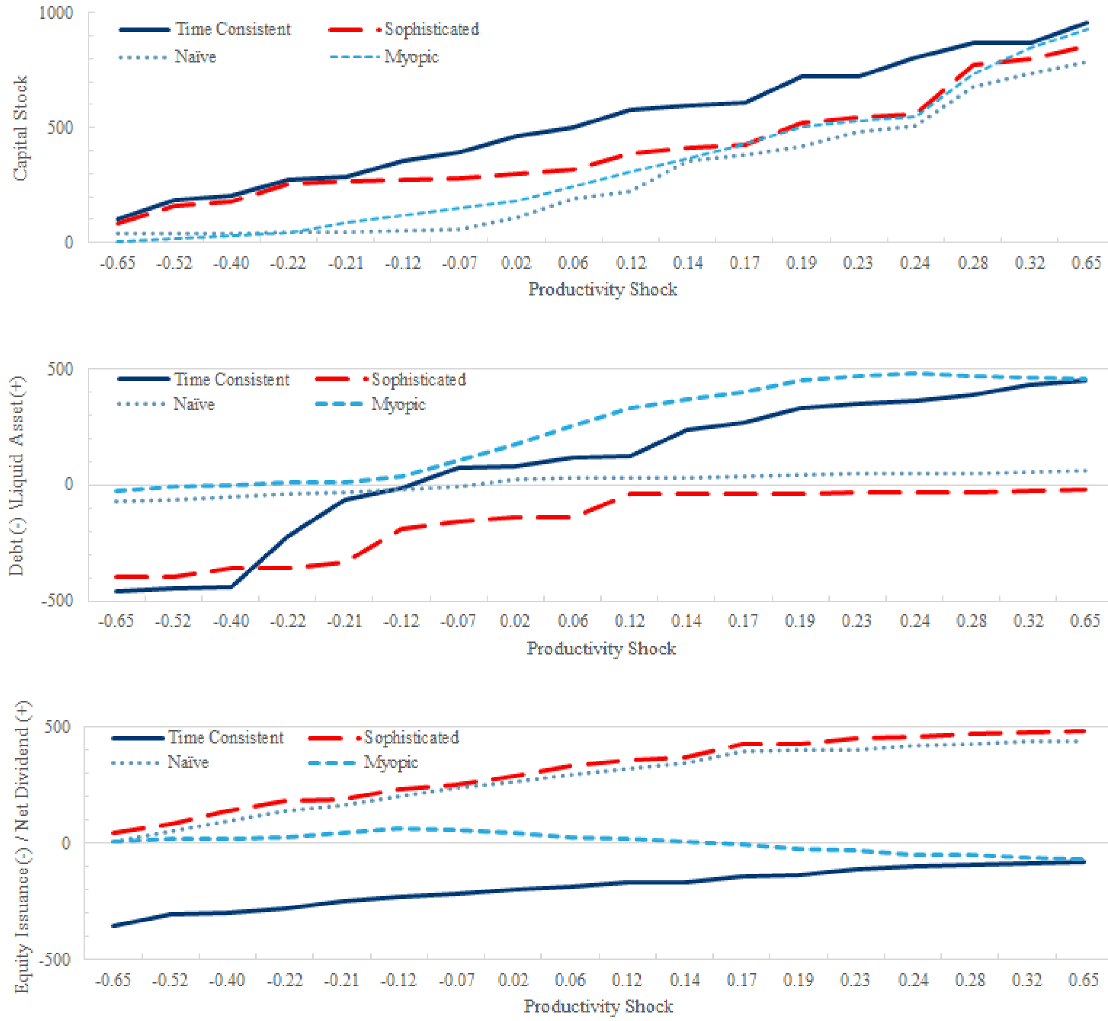

Figure 1.2 Simulation Results under Different Time Preferences

This figure graphs the simulation results for my dynamic investment model using parameters summarized by Table 1.6. In the model, I compare investment (plot 1), financing and dividend decisions (plot 2 and 3) of the firm with (i) a time-consistent manager, (ii) a sophisticated present-biased manager, (iii) a naïve time-inconsistent manager, and (iv) a myopic manager.

CHAPTER 2 CORPORATE SITE VISITS AND ITS DISCLOSURE REGULATION

1. Introduction

The prevalence and importance of ptivate interactions between corporate insiders and capital market participants have caused increasing attention from both academics and regulators. Researchers have been examining these private interactions, including conference presentations, analysts/investor days, private meetings and site visits, and have provided insightful analysis on the forms, causes and consequences of these private interactions. Despite that material information is prohibited to be disclosed during all types of face-to-face interactions, private interactions can still cause regulatory concern that these activities could increase the information gap between the participants and nonparticipants and thus deteriorate capital market efficiency. A natural research question is whether there is a need to introduce mandatory disclosure requirement towards private interactions. In this paper, not only do we study the impact of site visits on corporate information asymmetry, but also attempt to contribute to the literature on disclosure and regulation by examining the effectiveness of disclosure regulation on site visits in China.

Starting from 2009 in China, firms listed on the Shenzhen Stock Exchange (SZSE) are mandated to make disclosure of each site visit in their financial reports,[1] while firms listed on the Shanghai Stock Exchange (SSE) are not required (i.e., voluntary) to do. SSE firms are only required to submit the publicly unavailable summary reports to the China Securities Regulatory Committee (CSRC) and SSE.[2] This regulation difference thus officially makes two stock markets in China differentiated on this information disclosed to the public, thereby generating a great

[1] "Guidelines on Information Disclosure of Corporate Financial Reports, Document No.1". Available at SZSE's website.
[2]See SSE's website.

institutional setting to examine the effectiveness of this site visits disclosure regulation in China.

Using a proprietary dataset on site visits in China in the period from 2009 to 2012, this paper studies how corporate site visits affect information asymmetry and whether this impact is influenced by this regulation difference on site visit information. We obtain the proprietary reports on site visits to SSE firms from SSE and hand-collect the relevant information of these SSE firms. Combined with information collected from financial reports of SZSE firms, we investigate whether the impact of site visits on information asymmetry varies across the two markets. [3]

The intended objective of the regulation by the SZSE was to provide equal access to firm information.[4] According to SZSE, the mandated disclosure facilitates the transfer of nonmaterial, nonpublic information from visitors to other stakeholders and help analysts and investors market-wide to evaluate the accuracy and creditability of firm information. If equal access is improved via mandated disclosures, then the information asymmetry should be lowered under regulatory adoption (Eleswarapu et al., 2004).

Using both adverse selection component of bid-ask spread (Easley and O'hara, 1987; Glosten and Harris, 1988) and standard deviation among analyst forecasts as proxies for information asymmetry, we find that in general site visits reduce the information asymmetry. These results are consistent with the anecdotal evidence that site visits are one of the major information gathering activities for investors and analysts (e.g. Brown et al., 2015; Bushman et al., 2004). However, we find that the mandated disclosure of these visits has limited additional impact on information asymmetry as the decrease of information asymmetry due to site visits is not significantly different

[3] The dataset used by prior studies on corporate site visits in China (e.g. Cheng et al., 2015, 2016) only contains site visits to SZSE firms, which is publicly available. Site visits to SSE firms are not included in their data sample. Literature on site visits in the U.S market is rare because information on site visits is not publicly available in the U.S.
[4] Available at SZSE website.

between the regulated SZSE firms and unregulated SSE firms. These results are robust to different measures of site visit activities.

We also investigate whether disclosure regulation reduces the visiting analysts' and fund managers' private access to information. We repeat our analysis on site visits conducted by analysts and fund managers, respectively. Consistent with our main results, we find that the relationship between information asymmetry and visits by analysts or fund managers is neither significantly stronger nor significantly weaker for the regulated exchange market than the unregulated.

To supplement our investigation, we then analyze the information content of site visits using abnormal absolute market-adjusted returns in the three days around each visit. We find significantly higher abnormal returns during the site visits windows. However, the abnormal returns are not significantly different between firms that are mandated to disclose and those that are not. Collectively, these results support our conception that, ceteris paribus, the disclosure regulation on site visits by SZSE does not make any difference as opposed to SSE, an exchange market with no such regulation.

Our study extends the literature on private face-to-face interactions. Previous literature documents that private interactions facilitate information transfer from management to analysts and investors, and benefit all participants (e.g. Bushee et al., 2017; Green et al., 2014a; Soltes, 2014). As for site visits, it is found that site visits have significant information content and lead to improved analyst forecast accuracy (Cheng et al., 2015, 2016).[5] Our results demonstrate that the number of site visits is negatively correlated with adverse selection component of bid-ask spread

[5] The data sample from Cheng et al. (2015, 2016) are only SZSE firms that are mandated to disclosed site visit information. Our sample significantly differs from theirs in that our sample includes firms both with and without this mandatory disclosure regulation. Also differing from their papers, our paper tries to examine whether such regulation in one market with mandatory requirement of disclosure is superior to another market with no such regulation.

and analyst forecast dispersion, thus providing evidence that site visits can mitigate the information asymmetry problems. These findings may be important to other markets, specifically for those that are characterized by opaque information environments and relatively weak legal protection.

Our study also contributes to the literature on regulation of financial reporting and disclosure. By comparing the information asymmetry effect of site visits between regulated SZSE firms and unregulated SSE firms, our paper suggests that in China this disclosure regulation on site visit information has little impact on further reducing information asymmetries. Our results therefore could be of interest to regulators or policy makers.

The rest of the paper proceeds as follows. Section 2 presents the literature review and hypothesis development. Section 3 describes the sample and research method. Regression results on both all group and subgroups of site visits are reported in section 4. Section 5 analyzes the information content of site visits. Section 6 presents endogeneity analyses. Section 7 concludes.

2. Literature Review and Hypothesis Development

2.1 Corporate Site visits and other private interactions

Analysts and investors value the private interactions with corporate insiders (Kary, 2005; Wagner, 2005). Along with the growing number of private interactions among managers, employees, analysts, investors and other stakeholders in the capital markets, researchers have begun to examine the informational role of private interactions in the capital markets. In terms of the determinants of private interactions, prior studies indicate that hard-to-value firms, of which the demand of analysts and institutional investors for management access is greater, are associated with more conference presentations (Green et al., 2014a) and analyst/investor days (Kirk and Markov, 2016).

As for the consequences of private interactions, previous literature suggests that face-to-face interactions facilitate information transfer from management to analysts and investors. For example, Bushee et al. (2011) document a significant information content during conference presentations and find that the physical and social setting of conference influences the market reaction to conference presentation. Bushee et al. (2017) investigate the trade activities around invitation-only conferences and document increases in trade size around these events. For broker-hosted conferences, it is found that they provide benefits to all participating parties (Green et al., 2014a) and the price impacts of analyst recommendation changes is greater for analysts whose firm hosts conferences for the company (Green et al., 2014b). Soltes (2014) finds sell-side analysts produce additional research reports by privately meeting with management. Analyst/investor days are also found to convey a significant information content to the market (Kirk and Markov, 2016). Consistent with the notion that private meetings between management and investors increase investors' information advantage, Bushee et al. (2014) find significant larger abnormal market reactions during the road show flight window than other flight windows. Solomon and Soltes (2015) find that investors who privately meet with management trade simultaneously in the unusual way and such trades better predict future returns.

Compared with other forms of private interactions, corporate site visits are under-researched mainly because of the lack of data (Kirk and Markov, 2016; Soltes, 2014). Site visit is a prevalent and valuable form of information gathering activity in capital market (Brown et al., 2015). When analysts and/or investors visit the firm, they could not only talk with managers and/or employees, but also observe the company's operations and production activities. Therefore, site visits provide a distinctive opportunity for participants to know more about the company's assembly lines, business culture and employee morale through visual cues (Cheng et al., 2015, 2016). By exploiting the mandated disclosure requirement of SZSE firms, Cheng et al. (2015) demonstrate a significant market reaction around corporate site visits dates; and Cheng et al. (2016) find that analysts forecast accuracy increases because of site visits and the increased accuracy are greater for manufacturing firms.

In summary, the existing literature suggests that face-to-face interactions facilitate the information transfer from insiders to outside analysts and investors. We therefore conjecture that corporate site visits reduce the information asymmetry of the firms. We thus propose our first hypothesis as follows:

H1: Site visits reduce corporate information asymmetry.

2.2 Disclosure Regulation

2.2.1 Prior Literature

Regulations have been long shown to be crucial and important in governing financial reporting and disclosure. Prior literature suggests that the existence of market imperfections may explain the prevalence of disclosure regulations. Existing shareholders may concern about prospective investors' free ride on accounting information and thus underproduce information (Beaver, 1998; Watts and Zimmerman, 1986) . Leftwich (1980), among others, also points out that disclosure regulations may be driven by regulators' concern about the welfare of financially unsophisticated investors. As a result, the objective of regulations is to reduce the information gap among different capital market participants.

Another important research question in this field is to investigate whether disclosure regulation is useful in mitigating the information and agency problems in capital markets. A stream of literature addresses this question by examining the relationship between regulated accounting information and security prices. Existing evidence largely supports the informativeness of regulated financial disclosures (Kothari, 2001) but the extent of their relative informativeness varies largely across firms (Ball et al., 2000) and countries (Alford et al., 1993). However, one concern of this “capital market” research is that it does not answer the question that whether the relative informativess is significantly different from regulated and unregulated accounting information (Healy and Palepu, 2001). It follows that the existing evidence does not necessarily suggest that regulated disclosure provides more relevant information than does unregulated disclosure.

The accounting research also examines the effectiveness of disclosure regulation by investigating new financial reporting standards. For example, Eleswarapu et al. (2004) investigates how Regulation Fair Disclosure (Reg FD) enacted in 2000 impacts information asymmetry among investors. They use trading costs at earnings announcements as proxies for information asymmetry and find that information asymmetry decreases in the post-Reg FD period. These effects are more prononced for small and illiquid stocks. However, using firms exempted from Reg FD as the control group, Francis et al. (2006) find that changes in information proxies in the pre- versus post-Reg FD period are not significantly different between the treatment and control groups. Their results thus suggest that the Reg FD has limited impact on information environments of US firms.

In sum, literature on regulation disclosures provides evidence that regulated accounting information is valuable to investors. Regulations are different across countries. It is also possible that firms listed on different exchanges of the same country face different regulations. The effectiveness of regulation could be largely determined by the characteristics of information environments, and can vary systematically across firms and countries.

2.2.2 Disclosure Requirement of Site Visits in China

All firms listed on SSE and SZSE are required to report to the CSRC and the SSE/SZSE before and after each site visit.[6] These reports are not publicly available. In the Article 41 of Guidelines on Information Disclosure issued by CSRC in 2007, which is similar to the Regulation FD in U.S., CSRC prohibits firms to disclose any material information during the site visit and requires firms to refuse site visit requirements in the period close to earnings announcements. [7]

Starting from 2009, firms listed on SZSE are required to include the summary information of each site visit in their annual reports. The disclosure is mandated and strictly enforced. On the contrary, SSE does not require its listed firms to disclose site visit information, and few SSE firms make voluntary site visit disclosures.

The intended purpose of the mandated disclosure, according to SZSE, was to protect the welfare of relatively unsophisticated investors and to provide equal access to firm information.[8] According to SZSE, the mandated disclosure facilitates the transfer of nonmaterial, nonpublic information from those conduct site visits to other stakeholders. As a result, mandatory disclosure of site visit information would improve equal access by reducing the information gap between the visitors and non-visitors. If the equal access is guaranteed and improved via mandatory disclosures, then the information asymmetry in the capital market should be lower under regulatory adoption (Eleswarapu et al., 2004).

In addition, mandatory disclosure of site visit information may help investors to better evaluate the information environment of the company. Ceteris paribus, companies with more site visits are more likely to have greater investor recognition, better investor relationship and better information environment (Firth et al., 2015). The disclosure therefore facilitate the firm to attract investors and increase analyst coverage. Moreover, since research reports by sell-side analysts are

[6] See SSE's website.
[7] Available at CSRC's website.
[8] See SZSE's website.

free to the public in China, mandatory disclosure of site visit provides information about the frequency of interactions and about the relationship between the research analyst and the company, thereby enabling investors to better assess the accuracy and creditability of analyst forecasts and recommendations.

However, there are several factors that could make the regulation on the disclosure of site visit ineffective. First, similar to other private interactions, site visits potentially carries an information advantage – visitors could increase the "informativeness" of site visits by asking questions related to their private information, and/or confirm or supplement their private information by observing the operations and business units, as well as meeting with managers and employees of the company. Previous literature also suggests that the informtion content of disclosures depends on the investors' private information (Bushee et al., 2011; Holthausen and Verrecchia, 1990). It follows that the informativeness of mandated site visit disclosure relies on the personal information environment of visitors and non-visitors.

Second, site visits feature the opportunity to observe the business units, production lines and operation facilities. As a result, site visits are valuable because of this visual access to nonverbal cues (Cheng et al., 2015, 2016). These visual but nonverbal cues include knowledge of production activities, corporate cultural and employee morale. However, it is hard to reflect these nonverbal cues in the summary reports to disclosure.

Third, requiring companies to disclose site visits in their annual reports could not provide timely information to investors, especially under the regulation from CSRC that site visits should not be arranged in temporally proximate to earnings announcements. Instead of providing real-time information to non-visiting investors, summary reports in annual reports may simply confirm the information of non-visiting investors that is already available to them through other sources.

As a result, disclosures of site visits could have little impact on providing timely and relevant informtion to non-visitors.

In summary, whether mandated site visit disclosure is effective in reduing information asymmtry is an empirical question given the two-sided effects of this regulation. Our tests try to answer whether the mandatory disclosure regulation of site visits is superior to the non-mandatory approach to disclosure. Thus, we state the null form of our second hypothesis as follows:

$H2_0$: The negative effect of site visit on information asymmetry is more pronounced for SZSE firms that are mandated to make site visits disclosure than that for SSE firms facing a market approach to disclosure.

3. Sample and Methodology

3.1 Sample

Our sample of corporate site visits is from 2009 to 2012. As aforementioned, while all listed firms in China are required to submit summary reports of each site visit to the CSRC and SZSE/SSE, only firms listed on the SZSE are mandated to disclose site visit information in their financial reports. For all SSE firms of which the site visit information is not required to disclose and not publicly available, we exploit a proprietary dataset containing the summary reports submitted to the SSE and hand-collect the site visit information for these SSE listed firms. [9] We then supplement our data by hand-collecting the site visit information for all SZSE firms from their annual reports. For each record, we collect the names of visiting institutions or individuals, the date, location, and the main topics of discussion. We obtain data on stock returns, accounting

[9] We deeply thank Shanghai Stock Exchange for providing us this unique data on corporate site visits of SSE's listed firms.

items, and analyst forecasts from the CSMAR database and the high-frequency trade and quote data from GTA.

Table 2.1 provides summary statistics for our full sample and for the subsample of SZSE and SSE firms. As is shown, there are 4,939 observations for the full sample. On average, firms listed on the two markets are not significantly different in major financial characteristics such as sizes, institutional holdings and analyst followings (Chow tests not reported). Table 2.2 presents a Pearson correlation table of variables.

3.2 Research Design

3.2.1 Regression model for H1

We conduct the following regression to investigate whether corporate site visits reduce information asymmetry of firms in the China's stock markets:

$$Info\_Asy_{it} = \alpha + \beta N\_visit_{it} + \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \quad (2.1)$$

where $Info\_Asy_{it}$ is the proxy for information asymmetry of firm i in year t. We include year and industry dummies in the regression and calculate robust standard errors clustered at the firm level. We follow prior literature and construct two proxies for information asymmetry. Our first information asymmetry measure, the adverse selection component of the bid-ask spread or AS, is constructed based on the literature on market microstructure. We follow Easley and O'hara (1987), Glosten and Harris (1988), and Lin et al. (1995), and estimate the adverse selection component of bid-ask spread using the following model:

$$\Delta P_t = c_0 \left(Q_t - Q_{t-1}\right) + c_1 \left(Q_t V_t - Q_{t-1} V_{t-1}\right) + z_0 Q_t + z_1 Q_t V_t + e_t \quad (2.2)$$

where P is transaction price, V is observed number of shares traded on transaction t. The trade sign, Q , equals 1 if a transaction is buyer-initiated and -1 if it is seller-initiated. $z_0 + z_1V^*$ is AS , the adverse selection component of the bid-ask spread, with V^* stands for the median order size. Our second measure is the standard deviation in the analysts' EPS forecasts, $DISP$ in short.

N_visit_{it} is the frequency of site visits, calculated as the number of site visits during year t. $Control_{j,i,t}$ contain firms' characteristics, financial conditions and other variables that are shown by prior studies to influence information environment of the firm and are measured at the beginning of period. The firm-specific financial variables included are firm size, ROA, leverage, book-to-market, cash, capital expenditure, non-cash working capital, short-term debt, loss indicator, intangible assets and R&D intensity. We include prior returns, standard deviation of returns, beta, and non-tradable shares to describe the capital market characteristics. We also control for other factors shaping the information environment of the firm, including institutional ownership, and firm age. Finally, we control for whether the company is state owned, the separation of control rights and cash-flow rights, and the percentage of shares owned by the largest shareholder as proxies for corporate governance. Appendix 2.A summarizes the definition of all variables.

3.2.2 Regression model for H2

The second purpose of our research is to investigate whether the mandated disclosure of site visits is superior to a non-mandatory approach to disclosure. To fulfill this objective, we test if the reduction in information asymmetry is smaller for firms without this mandatory regulation (i.e. firms listed in SSE) using the following equation:

$$\begin{aligned} Info\_Asy_{it} &= \alpha + \beta N\_visit_{it} + \lambda N\_visit * If\_shanghai + \gamma If\_shanghai \\ &+ \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \end{aligned} \tag{2.3}$$

The interaction term, $N\_visit_{it} * If\_shanghai_{it}$, should be significantly positive if the effect of corporate site visits on the reduction of information asymmetry is relatively smaller for firms free from disclosure regulation. All other variables in Eq. (2.3) are the same to those in Eq. (2.1). Year and industry dummies are included and standard errors are clustered at firm level.

4. Results

4.1 Multivariate tests for H1

Regression results of how *AS* and *DISP* are influenced by the number of corporate site visits are reported in Table 2.3. In the first column, we use *AS*, the adverse selection component of bid-ask spread based on the market microstructure literature, as a proxy for information asymmetry. Higher *AS* indicates greater level of information asymmetry. The result that the coefficient for N_visit is negative and significant at the 5% level suggests that the adverse selection component of bid-ask spread is lower for firms with more site visits. Similarly, the second column demonstrates that the N_visit has a negative coefficient that is statistically significant at the 1% level, suggesting that more corporate site visits are associated with lower dispersion in analysts' forecasts.

Collectively, the results confirm our predication in H1 that investors' site visits reduce the amount of information asymmetry of the firm. This negative effect on information asymmetry exists for both SZSE and SSE firms. Our results are consistent with anecdotal evidence that site visits are considered as an major and prevalent form of information gathering activities for analysts and investors (Brown et al., 2015). These results are also consistent with findings from previous literature in that site visits facilitate the transfer of information from insiders to outsiders (Cheng et al., 2015, 2016).

4.2 Multivariate tests for H2

Results for the test of the effectiveness of disclosure regulation are presented in Table 2.4. We construct an indicator variable for firms without disclosure regulation ($If\_shanghai$) and use $N\_visit*If\_shanghai$ to capture the conditional effect of the number of site visits on information asymmetry. If the disclosure regulation of site visit information improves the equal access to information, as is expected by the regulator, the coefficient of $N\_visit*If\_shanghai$, should be significantly positive.

Similar to the regression results of Eq. (2.1), we continue to find that site visits reduce information asymmetry, as firms with more site visits have smaller adverse selection component of bid-ask spread and have lower forecast dispersion. However, we fail to find evidence that the regulation on site visit disclosure leads to more information asymmetry reduction than does a free market way to disclosure – the coefficient on the interaction term between $If\_shanghai$ and N_visit is insignificant, suggesting that the impact of site visits on information asymmetry for unregulatted SSE firms is not significantly different from SZSE firms facing mandatory disclosure requirement. These results reject the null hypothesis of our H2 and indicate that the mandatory requirement to disclose site visits has little impact on reducing the information gap between visitors and non-visitors and on diminishing the level of information asymmetry.

The ineffectiveness of this regulation, as we discussed before, may be due to the fact that site visits potentially provides visitors with an information advantage by allowing them to ask questions related to their private information (Bushee et al., 2011) and to assess visual but nonverbal cues by observing the company's production activities and operation facilities that are impossible to be reflected in the summary reports. Meanwhile, instead of delivering real-time information to non-visiting investors, requiring companies to disclose site visits in their financial reports may simply confirm the information of non-visiting investors that is already available to them through other sources.

4.3 Analysis of site visits by different participants

In this section, we analyze whether the disclosure regulation of site visit information decreases information asymmetry by reducing the institutional investors' and analysts' private access to information. Though all types of stakeholders could visit the company, analysts and institutional investors conduct most site visits. One reason is that site visits are not costless in terms of both money and time and they therefore will be conducted only if the expected benefits exceed the costs. For analysts and institutional investors with greater financial ability and more private information, the likelihood of obtaining useful information from site visits is higher.

The mechanism through which site visits reduce information asymmetry is different between fund managers' site visits and analysts': for site visits by fund managers, information asymmetry decreases because of the increases in stock liquidity resulted from trading activities; while analysts' site visits reduce information asymmetry by facilitating them to provide more precise reports (Cheng et al., 2016). It follows that the impact of disclosure regulation could vary across site visits by analysts and fund managers. Thus, it is interesting to investigate whether the information asymmetry effect of analysts'/fund managers' site visits differs among regulated and unregulated firms.

4.3.1 Site Visits by fund managers

Fund managers are financially sophisticated investors. While companies are required to take particular care not to release material information during site visits, fund managers could gather valuable information through site visits. By providing the opportunity to communicate with insiders and to observe production activities and business units, site visits allow fund managers to confirm and/or update their private information. The increased precision of information helps fund managers to make trading decisions. These trading activities contribute to information asymmetry reduction by increasing the liquidity of the stock.

Similar to our analysis on all site visits, we first test whether site visits by fund managers reduces information asymmetry using the following regression:

$$Info\_Asy_{it} = \alpha + \beta N\_fund_{it} + \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \tag{2.4}$$

where N_fund, is the number of fund managers' site visits during year t. All other variables in Eq. (2.4) are the same as Eq. (2.1). Year and industry dummies are include and standard errors are clustered at firm level. Panel A of Table 2.5 presents the results. In accordance with our prediction, we find that the adverse selection component and forecasts dispersion are smaller for firms with more fund managers' site visits: on average, one more site visit significantly reduces AS and $DISP$ by 0.0010 and 0.0009, respectively.

The objective of disclosure regulation by the SZSE is to reduce the information gap between vistors and non-visitors. To evaluate whether this purpose is fulfilled by reducing the fund managers' private access to information, we then run the following regression:

$$\begin{aligned} Info\_Asy_{it} = {} & \alpha + \beta N\_fund_{it} + \lambda N\_fund * If\_shanghai + \gamma If\_shanghai \\ & + \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \end{aligned} \tag{2.5}$$

Panel B of Table 2.5 reports the results of Eq. (2.5). Consistent with previous findings, we find that, controlling for other characteristics influencing information asymmetry, firms under disclosure regulation do not experience more reduction in information asymmetry because of site visits conducted by fund managers. The visits by fund managers reduce information asymmetry as the frequency of fund managers' visits is negatively associated with AS and $DISP$. However, our results suggest that the disclosure regulation is not superior to a non-madatory approach to disclosure.

4.3.2 Site visits by analysts

As the major information intermediary in capital markets, financial analysts gather information through public and private sources and make forecasts and recomendations. Existing literature generally supports the role of analysts in helping reducing the information asymmetry between management and investors (O'Brien and Bhushan, 1990). Corporate site visits facilitate analysts to gather information and improve their forecast accuracy (Brown et al., 2015; Cheng et al., 2016). As a result, site visits by analysts facilitate to reduce information asymmetry by increasing the accuracy of analyst reports.

To examine the effect of site visits on information asymmetry and the role of disclosure regulation in reducing the information gap between visiting analysts and other stakeholders, we calculate the frequency of site visits by analysts in each period, $N\_analyst$, as the number of analysts' site visits during year t. The two regression equations are as follows:

$$Info\_Asy_{it} = \alpha + \beta N\_analyst_{it} + \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \qquad (2.6)$$

$$\begin{aligned} Info\_Asy_{it} = {} & \alpha + \beta N\_analyst_{it} + \lambda N\_analyst * If\_shanghai + \gamma If\_shanghai \\ & + \sum_{j=1}^{k} \psi_j Control_{jit} + \varepsilon_{it} \end{aligned} \qquad (2.7)$$

where all other variables in Eq. (2.6) and Eq. (2.7) are the same as Eq. (2.1). Year and industry dummies are included and standard errors are clustered at firm level.

Panel A of Table 2.6 presents the regression results for Eq. (2.6). Again, we find that the number of site visits conducted by analysts is negatively associated with adverse selection component of bid-ask spread (AS) and forecasts dispersion ($DISP$). These results suggest that site visits by analysts help decrease information asymmetry by facilitating the transfer of information from managers to outsiders. Regression results for Eq. (2.7) are summarized in Panel B of Table 2.6. Similar to Table 2.4, we do not find evidence supporting the effectiveness of regulation. Specifically, our results show that the information asymmetry impact of analysts' site visits is not significantly different between the regulated and unregulated, as the coefficient of the interaction term is insignificant for all information asymmetry measures. Collectively, these findings indicate that the disclosure regulation on site visits is ineffective in decreasing the visiting analysts' private access to information.

5. Information Content Tests

To bring more robustness to our results, we next examine the information content of site visits and retest the effectiveness of regulation by comparing the information content in two markets. We measure the information content of site visits using abnormal absolute returns around the event (e.g. Bushee et al., 2011) . The three-day abnormal absolute return (ABN_ABSMAR) is calculated following Kirk and Markov (2016) with an estimation period of [-120, -30] and a three-day trading window [-1,+1] around each site visit. We also calculate the ABN_ABSMAR for visits conducted by analysts and fund managers, respectively.

Panel A of Table 2.7 presents mean, median, and percentage of positive ABN_ABSMAR around site visits of both markets. For all site visits, we document a significant increase in ABN_ABSMAR during the visit window. The mean ABN_ABSMAR of 0.095 during the site visit window represents a 13% increase over abnormal returns during the estimation period, suggesting that site visits conveys information. The mean ABN_ABSMAR for site visit conducted by analysts and fund managers are 0.134 and 0.095, respectively, and of statistical significance. The median ABN_ABSMARs are negative because only about 40% of the firms experience greater absolute returns during the site visit window. We relate our results to Bushee et al. (2011), who analyze the information role of conference presentations and document a similar great deal of cross-sectional variation. They argue that material information are not likely be disclosed during the event as the mean effects are small and the medians are significantly negative, suggesting that it is the private information of visitors that leads to the information content.

Panel B of Table 2.7 compares the information content of site visits between firms with regulation ($If\_Shanghai = 0$) and firms with a free market approach to disclosure ($If\_Shanghai = 1$). For all site visits, the mean ABN_ABSMAR for the regulated is 0.102 while the mean ABN_ABSMAR for the unregulated is 0.073. The difference in ABN_ABSMAR between the regulated and unregulated is insignificant, suggesting that the information content is not improved by mandated disclosure of site visit information. Results for site visits by fund managers and analysts are similar.

These results are consistent with our argument that regulation could be ineffective if the informativeness of site visits is closely related to the private information of the attendees (Cheng et al., 2016), because private information affects the extent to which visitors can update their prior beliefs about the company with information collected during site visits. The result that the information content reflected in the abnormal absolute returns is not significantly between regulated and unregulated supports our argument that the disclosure regulation on site visits could be ineffective because the "mosaic" information transferred during site visits may only be valuable in combination of the participants' private information.

6. Endogeneity between Dispersion in Analysts' Forecast and Site Visits

In the main test, we investigate whether site visits lead to lower dispersion in analysts' forecasts ($DISP$) and compare the effect of site visit on $DISP$ between regulated and unregulated markets. However, the decision to visit a firm may be endogenous – analysts may pay more visits to firms with higher dispersion of analysts' forecasts, leading to a positive association between whether a firm receives site visits and dispersion in analysts' forecasts. This endogenous concern is less important for adverse selection component of bid-ask spread, which is our first measure of information asymmetry.

To address this possible endogenous problem, we retest our hypotheses via Heckman two-stage selection model. We consider an endogenous indication variable, D_visit, which equals 1 if the firm receives at least one site visit during the year, and 0 otherwise. The exclusion restriction in our model is the logarithm of the annual passenger volume ($Log\ Passenger\ Volume$) of the province where the company headquarter is located. We obtain the data for passenger volume of each province during our sample period from the National Bureau of Statistics of China.[10] Since visiting costs in terms of both time and comfort are lower for visits to and within provinces with higher passenger volume, we expect that companies located in provinces with higher passenger volume are more likely to receive site visits, i.e., a positive association between the probability of receiving site visits and $Log\ Passenger\ Volume$. At the same time, there is little evidence that $Log\ Passenger\ Volume$ has direct impact on the dispersion in analysts' forecasts.

Table 2.8 presents the results for the Heckman selection model. In stage one, we estimate the choice of whether to visit a firm using $Log\ Passenger\ Volume$ and other control variables in Eq.

[10] Available at the website of the National Bureau of Statistics of China.

(2.1) using probit. Regression results for the first stage are presented in the first column of Table 2.8. Consistent with our prediction, the coefficient of *Log Passenger Volume* is positive and of statistical significance. In stage two, we add the inverse Mills' ratio to control for the selection bias.

Results of the second state are summarized in the second and third column of Table 2.8. Column (2) tests whether the negative effect of site visits on forecast dispersion persists after controlling for the endogeneity concern. The coefficient on endogeneity choice variable is -0.0140 and significant, suggesting that site visits help to reduce dispersion in analysts' forecasts. In Column (3), we examine whether the disclosure regulation by SZSE influence the negative effect of site visits. Similar to our previous findings, we find that though firms receiving at least one site visit have significantly lower forecast dispersion, this effect is not significantly different between the regulated SZSE firms and the unregulated SSE firms. Note that the coefficient on the inverse Mills ratio is not significant in both tests, suggesting that selection problem is not a significant concern for our investigation.

7. Conclusion

In this paper, we examine two research questions: 1) whether corporate site visits reduce the information asymmetry; and 2) whether the information asymmetry effect of corporate site visits is enhanced by the disclosure regulation on site visit information. Towards that, we exploit a unique institutional setting in China where only one stock exchange (SZSE) requires its listed firms to disclose site visit information to the public. The exploitation of a set of proprietary site visit records compiled by unregulated SSE firms provides us a distinctive opportunity to compare the information asymmetry effect of site visits between the regulated SZSE and unregulated SSE firms.

Using a proprietary sample of site visits in China from 2009 to 2012, we find that the number of corporate site visits is negatively associated with information asymmetry. These findings are consistent with the notion that site visit is an important type of information acquisition activities (e.g. Bushman et al., 2004). However, further investigation reveals that the mandatory disclosure requirement by SZSE has no significant impact on the negative information asymmetry effect of site visits, as the reductions are not significantly different between the regulated SZSE and unregulated SSE firms. These results are robust to different measures of site visit activities. We also investigate the information content of site visits and document a significant mean abnormal return reaction to site visits. The abnormal returns around site visits, however, are not significant between SZSE and SSE firms.

These findings contribute to the literature by documenting how corporate site visits affect the information asymmetry and how disclosure regulation of site visit information influences this impact. In this regard, we relate our study to the literature that investigates private interactions between corporate insiders and outsiders. Existing literature suggests these face-to-face interactions facilitate information transmission (e.g. Bushee et al., 2011; Cheng et al., 2016; Green et al., 2014b). Our investigation of corporate site visits extends the literature by showing that corporate site visits reduce information asymmetry. In addition, by examing the conditional information asymmetry effect on SZSE and SSE firms, our findings suggest that this disclosure regulation by SZSE is ineffective in reducing information asymmetry. These results could be of interest to regulators.

Appendix 2.A Variable Definitions

Variable	Definition
AS	The adverse selection component of the bid-ask spread estimated using high frequency trading data. Following Easley and O'Hara (1987), Glosten and Harris (1988), and Lin et al. (1995), we decompose the bid-ask spread to calculate its adverse selection component using the following structural model: $\Delta P_t = c_0(Q_t - Q_{t-1}) + c_1(Q_t V_t - Q_{t-1}V_{t-1}) + z_0 Q_t + z_1 Q_t V_t + e_t$ in which *P* is transaction price, *V* is observed number of shares traded on transaction *t*, and *Q* is trade sign which equals 1 for a buyer-initiated transaction and -1 for a seller-initiated transaction. $z_0 + z_1 V^*$ is the adverse selection component of the bid-ask spread, where V^* is the median order size.
DISP	Dispersion in analysts' forecast, are measured by the standard deviation in the analysts' EPS forecasts.
ABN_ABSMAR	The three-day absolute market-adjusted returns less the mean three-day absolute market-adjusted returns from the estimation period [-120,-30], divided by the standard deviation of the mean absolute market-adjusted returns from the same estimation period.
N_visit	The number of site visits during a year.
If_shanghai	1 if the firm is listed in SSE. Firms listed in SSE are not required to disclose site visit information in their annual reports.
N_analysts	The number of analysts' site visits during a year.
N_fund	The number of fund managers' site visits during a year.
Log Size	The logarithm of total assets.
ROA	Earnings before extraordinary items divided by total assets at the end of period.
Leverage	Long-term debt plus long-term debt in current liabilities scaled by total assets at the end of period.
Log Age	The logarithm of the number of years since the foundation of the firm.
Book-to-Market	Book value of equity divided by market value of equity.
CASH	The item of cash scaled by the total assets.
Capital Expenditure	Cash paid to acquire fixed-assets, construction-in-process, intangible assets, and other long-term assets minus proceeds from disposal of fixed assets, divided by total assets.
Non-cash Working Capital	Short-term assets minus current liabilities minus cash, scaled by total assets.
Short-term Debt	The item of Short-term debt scaled by total asset.
Loss	1 if the fiscal quarters' net income before extraordinary items is negative, and 0 otherwise.
Intangibles	Recognized intangibles plus goodwill scaled by total assets.
R&D intensity	Research and development expenses divided by total assets. Following Koh and Reeb (2015), we replace missing values with the industry median of R&D intensity for the same period, if the latter is also missing, we then set R&D intensity to 0.
Institutional Holdings	The percentage of shares held by institutional investors. Assumed to be 0 for any period in which the company is listed on an exchange, but no date is available in the institutional ownership dataset.

Prior Returns	Market-adjusted buy-and-hold returns over a year period at the prior fiscal year-end, with a minimum of 50 trading days.
Std. Dev. of Returns	Standard deviation of daily returns over a year period at the prior fiscal year-end, with a minimum of 50 trading days.
Beta	Beta value calculated using the CAPM.
Non-tradable Shares	The percentage of shares that are prohibited to trade in the market to the total shares outstanding.
State owned	1 if the firm is state-owned.
Separation	The separation of control rights and cash-flow rights.
Largest Shareholder Holdings	The percentage of shares held by the largest shareholder.
Log Passenger Volume	The logarithm of annual passenger volume of the province where the company's headquarter locates.

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Table 2.1 Summary Statistics

	All Firms			Firms listed in SZSE (*if_shanghai* = 0)			Firms listed in SSE (*if_shanghai* = 1)		
Variable	N	Mean	STD	N	Mean	STD	N	Mean	STD
Information Asymmetry Measures									
AS	4,198	0.0876	0.2895	2,193	0.1259	0.3516	2,005	0.0457	0.1924
DISP	3,420	0.1380	0.1634	1,799	0.1460	0.1656	1,621	0.1290	0.1604
Site Visits Variables									
N_visit	4,198	7.0958	17.9647	2,193	9.1327	20.5813	2,005	4.8678	14.2500
N_fund	4,198	3.3826	9.9107	2,193	4.3092	11.2866	2,005	2.3691	8.0251
N_analyst	4,198	2.6663	6.7394	2,193	3.5139	7.9102	2,005	1.7392	5.0033
Control Variables									
Log Size	4,198	21.8648	1.2442	2,193	21.5301	1.0815	2,005	22.2308	1.3062
ROA	4,198	0.0492	0.8162	2,193	0.0443	1.1126	2,005	0.0545	0.2025
Leverage	4,198	0.0948	0.1273	2,193	0.0714	0.1147	2,005	0.1203	0.1354
Log Age	4,198	2.5064	0.4274	2,193	2.4064	0.4831	2,005	2.6157	0.3230
Book-to-Market	4,198	0.4132	0.2887	2,193	0.3848	0.2696	2,005	0.4443	0.3052
CASH	4,198	0.2025	0.1478	2,193	0.2351	0.1661	2,005	0.1669	0.1147
Capital Expenditure	4,198	0.0669	0.0644	2,193	0.0737	0.0648	2,005	0.0594	0.0631
Non-Cash Working Capital	4,198	-0.0689	2.1440	2,193	-0.0652	2.9562	2,005	-0.0729	0.2607
Short-term Debt	4,198	0.4220	2.1425	2,193	0.4208	2.9560	2,005	0.4233	0.2374
Loss	4,198	0.0565	0.2308	2,193	0.0470	0.2116	2,005	0.0668	0.2498
Intangibles	4,198	0.0541	0.0693	2,193	0.0516	0.0540	2,005	0.0569	0.0828
R&D Intensity	4,198	0.0308	0.4180	2,193	0.0390	0.5663	2,005	0.0218	0.1221
Institutional Holdings	4,198	0.3598	0.2366	2,193	0.3262	0.2358	2,005	0.3965	0.2321
Prior Returns	4,198	1.2060	0.9698	2,193	1.2118	0.9879	2,005	1.1998	0.9498
Std. Dev. Of Returns	4,198	0.0346	0.0361	2,193	0.0359	0.0462	2,005	0.0331	0.0195
Beta	4,198	1.0125	0.2017	2,193	1.0233	0.2132	2,005	1.0007	0.1877
Non-Tradable Shares	4,198	0.3150	0.2776	2,193	0.3915	0.2814	2,005	0.2314	0.2476
State owned	4,198	0.0386	0.1926	2,193	0.0415	0.1995	2,005	0.0354	0.1849
Separation	4,198	6.2146	8.5391	2,193	6.2465	8.4025	2,005	6.1798	8.6879
Largest Shareholder Holdings	4,198	0.3745	0.1568	2,193	0.3656	0.1513	2,005	0.3844	0.1620

This table presents the summary statistics of variables. See Appendix A for Variable Definitions. Information Asymmetry measures the adverse selection component of bid-ask spread *AS* (Easley and O'Hara, 1987; Glosten and Harris, 1988; Lin et al., 1995) and the standard deviation of earnings forecasts made by analysts one month prior to the year end (scaled by the absolute mean), *DISP*. *N_visit*, *N_fund*, and *N_annalysts* are the total number of site visits, visits conducted by fund and visits by analysts in each year, respectively. *If*_shanghai is an indicator variable that equals to 1 if the firm is listed in SSE and 0 otherwise. Firms listed in SSE (*If_shanghai* = 1) are not regulated to disclose site visit information, while firms listed in SZSE (*If_shanghai* = 0) are required to disclose site visit information. Definitions of all variables are summarized in Appendix 2.A.

Table 2.2 Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1.AS	1.0000											
2.DISP	0.0417*	1.0000										
3.N_visit	-0.0526*	-0.0270	1.0000									
4.N_fund	-0.0498*	-0.0277	0.9519*	1.0000								
5.N_analyst	-0.0560*	-0.0235	0.9400*	0.8752*	1.0000							
6.Log Size	-0.1401*	0.0914*	0.1899*	0.1802*	0.2033*	1.0000						
7.ROA	0.0094	0.1468*	0.0097	0.0092	0.0092	0.1283*	1.0000					
8.Leverage	-0.0883*	0.0078	0.0698*	0.0520*	0.0741*	0.4129*	-0.0082	1.0000				
9.Log Age	-0.0742*	-0.0295	0.1712*	0.1431*	0.1690*	0.1609*	-0.0093	0.2054*	1.0000			
10.Book-to-Market	-0.1399*	-0.0977*	0.0505*	0.0475*	0.0655*	0.4155*	0.0077	0.2260*	0.0972*	1.0000		
11.CASH	0.1342*	0.0837*	-0.0518*	-0.0395*	-0.0562*	-0.2155*	-0.0120	-0.3529*	-0.2600*	-0.1765*	1.0000	
12.Capital Expenditure	-0.0193	0.0487*	-0.0160	-0.0006	-0.0070	0.0781*	0.0184	0.1801*	-0.1977*	0.0504*	-0.0845*	1.0000
13.Non-Cash Working Capital	0.0096	-0.0023	0.0014	0.0022	0.0014	0.1186*	0.9814*	-0.0112	-0.0236	0.0202	-0.0314*	0.0101
14.Short-term Debt	-0.0075	0.0103	-0.0005	-0.0011	-0.0015	-0.1216*	-0.9821*	-0.0066	0.0220	-0.0298	0.0178	-0.0368*
15.Loss	-0.0279	0.0023	-0.0164	-0.0231	-0.0246	-0.0811*	-0.1120*	0.0813*	0.0696*	0.0223	-0.1173*	-0.0644*
16.Intangibles	-0.0226	-0.0460*	0.0338*	0.0260	0.0304*	-0.0281	0.0138	0.0197	0.0542*	-0.0248	-0.1068*	0.0801*
17.R&D Intensity	0.0142	0.0445*	-0.0052	-0.0140	-0.0151	-0.1720*	-0.9310*	0.0277	0.0084	-0.0477*	0.0719*	-0.0283
18.Institutional Holdings	0.0419*	0.1066*	0.1004*	0.1052*	0.1017*	0.2691*	0.0416*	0.0556*	0.0884*	-0.1443*	-0.0082	0.0357*
19.Prior Returns	0.0789*	0.0956*	0.0311*	0.0191	0.0208	-0.0685*	-0.0073	-0.0177	-0.0035	-0.4049*	0.0178	-0.0685*
20.Std. Dev. Of Returns	-0.0134	-0.0207	-0.0042	-0.0141	-0.0203	-0.0895*	-0.0149	-0.0169	-0.0689*	-0.0273	0.0019	0.0074
21.Beta	-0.0607*	-0.0545*	-0.0244	-0.0325*	-0.0294	-0.1096*	0.0429*	0.0145	0.0199	0.0118	-0.0903*	-0.0005
22.Non-Tradable Shares	0.0747*	0.0557*	-0.0790*	-0.0737*	-0.0837*	-0.1010*	-0.0111	-0.1219*	-0.4136*	-0.0184	0.2661*	0.1432*
23.State owned	0.0027	-0.0002	-0.0106	-0.0079	-0.0079	-0.0116	0.0022	0.0023	-0.0152	-0.0336*	-0.0074	0.0092
24.Separation	0.0050	0.0530*	0.0507*	0.0396*	0.0413*	0.0178	0.0130	-0.0101	0.0611*	0.0087	-0.0167	-0.0276
25.Largest Shareholder Holdings	0.0160	0.0294	-0.0241	-0.0313*	-0.0188	0.2656*	0.0214	0.0669*	-0.1438*	0.0517*	0.0118	-0.0034

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
13.Non-Cash Working Capital	1.0000											
14.Short-term Debt	-0.9963*	1.0000										
15.Loss	-0.0875*	0.0815*	1.0000									
16.Intangibles	-0.0027	-0.0184	0.0141	1.0000								
17.R&D Intensity	-0.9492*	0.9496*	0.0768*	-0.0130	1.0000							
18.Institutional Holdings	0.0184	-0.0200	-0.1087*	-0.0064	-0.0296	1.0000						
19.Prior Returns	-0.0154	0.0184	-0.0329*	0.0109	0.0160	0.0845*	1.0000					
20.Std. Dev. Of Returns	-0.0098	0.0138	0.0182	-0.0127	0.0102	-0.1227*	0.3418*	1.0000				
21.Beta	0.0663*	-0.0599*	-0.0107	-0.0546*	-0.0669*	-0.1990*	0.1467*	0.3879*	1.0000			
22.Non-Tradable Shares	-0.0008	0.0037	-0.0385*	-0.0372*	0.0134	-0.4625*	-0.0590*	0.1453*	-0.0406*	1.0000		

23.State owned	0.0027	-0.0043	0.0099	-0.0360*	-0.0037	0.0590*	0.0079	0.0137	-0.0044	-0.0346*	1.0000	
24.Separation	0.0081	-0.0044	-0.0281	-0.0210	-0.0181	0.0821*	0.0232	0.0279	0.0528*	-0.0198	0.0339*	1.0000
25.Largest Shareholder Holdings	0.0123	-0.0102	-0.0421*	-0.0560*	-0.0242	0.1374*	0.0066	0.0462*	-0.0853*	0.2842*	0.0248	0.1135*

	(25)
25.Largest Shareholder Holdings	1.0000

Table 2.2 represents Pearson correlations. * indicates statistical significance at the 5 percent level in a two-tailed test. See Appendix for Variable Definitions.

Table 2.3 Information Asymmetry and Number of Site Visits

VARIABLES	(1) **AS**	(2) **DISP**
N_visit	-0.0003**	-0.0004***
	(-1.97)	(-3.06)
Log Size	-0.0408***	0.0165***
	(-8.05)	(3.34)
ROA	-0.0084	0.3545***
	(-0.31)	(4.94)
Leverage	-0.0031	0.1068***
	(-0.08)	(3.33)
Log Age	-0.0008	0.0019
	(-0.05)	(0.24)
Book-to-Market	0.0324**	-0.0312*
	(2.47)	(-1.95)
CASH	0.1035**	0.0742**
	(2.07)	(2.57)
Capital Expenditure	-0.0460	0.0976**
	(-0.62)	(2.19)
Non-Cash Working Capital	0.0588**	-0.0256
	(2.10)	(-1.10)
Short-term Debt	0.0399	0.0501**
	(1.39)	(2.01)
Loss	0.0040	0.0571***
	(0.31)	(3.03)
Intangibles	-0.0127	-0.0951***
	(-0.23)	(-2.66)
R&D Intensity	0.0623	0.3192
	(1.58)	(0.97)
Institutional Holdings	0.1216***	0.0534***
	(4.30)	(3.52)
Prior Returns	0.0091	0.0305***
	(0.95)	(5.11)
Std. Dev. Of Returns	0.0145	-0.1843**
	(0.09)	(-2.22)
Beta	-0.0690**	-0.0287*
	(-2.36)	(-1.74)
Non-Tradable Shares	0.1061***	0.0661***
	(3.85)	(4.61)
State owned	0.0030	-0.0001
	(0.19)	(-0.01)
Separation	0.0001	0.0006
	(0.29)	(1.62)
Largest Shareholder Holdings	0.0164	-0.0645***
	(0.44)	(-2.92)

Constant	0.8420***	-0.3141***
	(7.39)	(-2.93)
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0780	0.1070

This table presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_visit_{it} + \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t}$$

The dependent variable is the proxy for information asymmetry. We follow prior literature and use two variables to measure the level of information asymmetry of the stock: the adverse selection component of bid-ask spread *AS* (Easley and O'Hara, 1987; Glosten and Harris, 1988; Lin et al., 1995) and the standard deviation of earnings forecasts made by analysts one month prior to the year end (scaled by the absolute mean), *DISP*. *N_visit* is the total number of site visits in each year. $Control_{j,i,t-1}$ are control variables suggested by prior literature to influence information asymmetry. Definitions of all variables are summarized in Appendix 2.A. Year and industry fixed effect are included. Standard errors are clustered at firm level. t-statistics in parentheses. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively.

Table 2.4 Information Asymmetry, Site Visits, and Disclosure Regulation

VARIABLES	(1) **AS**	(2) **DISP**
N_visit	-0.0005**	-0.0006***
	(-2.26)	(-3.84)
N_visit*if_shanghai	-0.0001	0.0003
	(-0.21)	(0.97)
If_shanghai	-0.0453***	-0.0228***
	(-4.54)	(-2.83)
Log Size	-0.0354***	0.0194***
	(-6.65)	(3.65)
ROA	-0.0073	0.3490***
	(-0.29)	(4.91)
Leverage	0.0028	0.1088***
	(0.08)	(3.40)
Log Age	0.0054	0.0054
	(0.34)	(0.67)
Book-to-Market	0.0261**	-0.0342**
	(2.01)	(-2.16)
CASH	0.0913*	0.0706**
	(1.83)	(2.43)
Capital Expenditure	-0.0727	0.0858*
	(-0.98)	(1.92)
Non-Cash Working Capital	0.0553**	-0.0262
	(2.00)	(-1.13)
Short-term Debt	0.0369	0.0504**
	(1.30)	(2.01)
Loss	0.0042	0.0560***
	(0.33)	(2.97)
Intangibles	-0.0054	-0.0906**
	(-0.10)	(-2.54)
R&D Intensity	0.0638*	0.3202
	(1.68)	(0.98)
Institutional Holdings	0.1190***	0.0518***
	(4.24)	(3.41)
Prior Returns	0.0092	0.0306***
	(0.97)	(5.12)
Std. Dev. Of Returns	0.0127	-0.1861**
	(0.08)	(-2.35)
Beta	-0.0730**	-0.0297*
	(-2.50)	(-1.80)
Non-Tradable Shares	0.0881***	0.0573***
	(3.22)	(3.98)
State owned	0.0003	-0.0012
	(0.02)	(-0.07)
Separation	0.0001	0.0006
	(0.19)	(1.58)

Largest Shareholder Holdings	0.0270	-0.0583***
	(0.72)	(-2.67)
Constant	0.7527***	-0.3683***
	(6.34)	(-3.22)
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0826	0.1097

This table presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_visit_{it} + \lambda N\_visit_{it} * If\_shanghai_{it} + \gamma If\_shanghai_{it}$$
$$+ \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t}$$

The dependent variable is the proxy for information asymmetry. We follow prior literature and use two variables to measure the level of information asymmetry of the stock: the adverse selection component of bid-ask spread *AS* (Easley and O'Hara, 1987; Glosten and Harris, 1988; Lin et al., 1995) and the standard deviation of earnings forecasts made by analysts one month prior to the year end, *DISP*. *N_visit* is the total number of site visits in each year. *If*_shanghai is an indicator variable that equals to 1 if the firm is listed in SSE and 0 otherwise. Firms listed in SSE (*If_shanghai* = 1) are not regulated to disclose site visit information, while firms listed in SZSE (*If_shanghai* = 0) are required to disclose site visit information. $Control_{j,i,t-1}$ are control variables suggested by prior literature to influence information asymmetry. Definitions of all variables are summarized in Appendix 2.A. Year and industry fixed effect are included. Standard errors are clustered at firm level. t-statistics in parentheses. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively.

Table 2.5 Site Visits by Different Market Participants

Panel A: Information Asymmetry and Site Visits by Fund

	(1)	(2)
VARIABLES	**AS**	**DISP**
N_fund	-0.0005**	-0.0007***
	(-1.97)	(-3.20)
Control Variables	YES	YES
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0780	0.1070

Panel B: Information Asymmetry, Site Visits by Fund and Disclosure Regulation

	(1)	(2)
VARIABLES	**AS**	**DISP**
N_fund	-0.0006	-0.0009***
	(-1.51)	(-3.42)
N_fund*if_shanghai	-0.0007	0.0003
	(-1.43)	(0.52)
If_shanghai	-0.0418***	-0.0204**
	(-4.39)	(-2.57)
Control Variables	YES	YES
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0824	0.1093

Panel A of this table presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_fund_{it} + \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t} \ ,$$

and Panel B presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_fund_{it} + \lambda N\_fund_{it} * If\_shanghai_{it} + \gamma If\_shanghai_{it} + \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t}$$

The dependent variable is the proxy for information asymmetry. We follow prior literature and use two variables to measure the level of information asymmetry of the stock: the adverse selection component of bid-ask spread *AS* (Easley and O'Hara, 1987; Glosten and Harris, 1988; Lin et al., 1995) and the standard deviation of earnings forecasts made by analysts one month prior to the year end, *DISP*. *N_fund* is the total number of site visits by fund in each year. *If_*shanghai is an indicator variable that equals to 1 if the firm is listed in SSE and 0 otherwise. Firms listed in SSE (*If_shanghai* = 1) are not regulated to disclose site visit information, while firms listed in SZSE (*If_shanghai* = 0) are required to disclose site visit information. $Control_{j,i,t-1}$ are control variables suggested by prior literature to influence information asymmetry. Definitions of all variables are summarized in Appendix 2.A. Year and industry fixed effect are included. Standard errors are clustered at firm level. t-statistics in parentheses. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively.

Table 2.6 Information Asymmetry, Site Visits by Analysts and Disclosure Regulation

Panel A: Information Asymmetry and Site Visits by Analysts		
	(1)	(2)
VARIABLES	**AS**	**DISP**
N_analysts	-0.0009**	-0.0010***
	(-2.32)	(-2.62)
Control Variables	YES	YES
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0781	0.1064

Panel B: Information Asymmetry, Site Visits by Analysts and Disclosure Regulation		
	(1)	(2)
VARIABLES	**AS**	**DISP**
N_analysts	-0.0017***	-0.0015***
	(-2.90)	(-3.17)
N_analysts*If_Shanghai	0.0001	0.0007
	(0.18)	(0.85)
If_shanghai	-0.0473***	-0.0228***
	(-4.68)	(-2.81)
Control Variables	YES	YES
Year dummies	YES	YES
Industry dummies	YES	YES
Observations	4,198	3,420
R Squared	0.0828	0.1091

Panel A of this table presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_analysts_{it} + \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t} \ ,$$

and Panel B presents the results for the following regression:

$$Info\_Asy_{i,t} = \alpha + \beta N\_analysts_{it} + \lambda N\_analysts_{it} * If\_shanghai_{it} + \gamma If\_shanghai_{it}$$

$$+ \sum_{j=1}^{k} \psi_j Control_{j,i,t} + \varepsilon_{i,t}$$

The dependent variable is the proxy for information asymmetry. We follow prior literature and use two variables to measure the level of information asymmetry of the stock: the adverse selection component of bid-ask spread *AS* (Easley and O'Hara, 1987; Glosten and Harris, 1988; Lin et al., 1995) and the standard deviation of earnings forecasts made by analysts one month prior to the year end, *DISP*. *N_analysts* is the total number of site visits by analysts in each year. *If*_shanghai is an indicator variable that equals to 1 if the firm is listed in SSE and 0 otherwise. Firms listed in SSE (*If_shanghai* = 1) are not regulated to disclose site visit information, while firms listed in SZSE (*If_shanghai* = 0) are required to disclose site visit information. $Control_{j,i,t-1}$ are control variables that suggested by prior literature to influence information asymmetry. Definitions of all variables are summarized in Appendix 2.A. Year and industry fixed effect are included. Standard errors are clustered at firm level. t-statistics in parentheses. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively.

Table 2.7 Information Content of Site Visits

Panel A : Information Content of Site Visits for All Firms

	Abnormal Market-adjusted Return during [-1,+1]				
	Mean		Median		Pct>0
All site visits	0.095	***	-0.252	***	40.03%
Visits by analysts	0.135	***	-0.400	***	40.03%
Visits by fund	0.095		-0.240	***	40.15%

Panel B : Information Content of Site Visits for Regulated and Unregulated

		Abnormal Market-adjusted Return during [-1,+1]				
	If_shanghai	Mean		Median		Pct>0
All site visits	0	0.102	***	-0.254	***	40.08%
	1	0.074	***	-0.247	***	39.86%
	Difference	0.028		-0.007		
Visits by analysts	0	0.140	***	-0.396	***	39.66%
	1	0.123	**	-0.403	***	40.92%
	Difference	0.017		0.008		
Visits by fund	0	0.093	***	-0.244	***	40.03%
	1	0.101	***	-0.228	***	40.42%
	Difference	-0.008		-0.017		

This table provides mean, medians and percentage of positive values of stock market reaction during the three-day event window around site visits. Day 0 is the event date. *Absolute market-adjusted abnormal return during [-1,+1]* is defined as the absolute value of three-day market-adjusted returns less the mean absolute value of three-day market-adjusted returns during the estimation period. The estimation period begins 120 days prior to the site visit and ends 30 days prior to the event. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively, using a two-tailed tests (mean) and a Wilcoxon signed rank test (medians).

Table 2.8 Endogeneity Test

VARIABLES	N_visit	DISP	DISP
N_visit		-0.0004**	-0.0006***
		(-2.32)	(-2.62)
N_visit*If_Shanghai			0.0003
			(0.86)
If_Shanghai			-0.0233*
			(-1.70)
Log Passenger Volume	0.0896***		
	(3.04)		
		-0.0909	-0.0558
Inverse Mills' Ratio		(-1.02)	(-0.62)
Control Variables	YES	YES	YES
Year dummies	YES	YES	YES
Industry dummies	YES	YES	YES
Observations	3,985	3,985	3,985

This table presents the results for the endogeneity test using Heckman selection model. The exclusion restriction is *Log Passenger Volume*, which is the logarithm of one plus the annual volume of passengers for the province in which the headquarters of a listed firm locates. Year and industry fixed effect are included. t-statistics in parentheses. ***, **, and * indicates significance level of 1%, 5% and 10%, respectively.

CHAPTER 3 CORPORATE HEDGING IN INCOMPLETE MARKETS: A SOLUTION UNDER PRICE TRANSMISSION[1]

1. Introduction

A firm has input and output price risk exposures, but it is not often that all these price risks could be eliminated through exchange traded futures contracts as in incomplete markets, futures contracts are only existed for a limited number of assets. Though forward contracts are alternatives, they may be too expensive. If an appropriate related futures contract is not available for the input/output side, the firm may remain unhedged to that side.

However, vertical transmission of shocks among various levels of the market renders price transmission (PT, hereafter) along the supply chain, making one-side hedge riskier – profit volatility may actually be higher than remaining both sides exposed. For example, COFCO TUNHE (600737.SH), a Chinese company producing sugar from sugar beets, had a CN¥ 308 million losses from hedging its sugar sales in 2010. This occurred because sugar prices in China climbs nearly 66 percent and sugar beet prices also rise. Therefore, the fluctuation of its net profit from selling sugar increased.

In this paper, we attempt to provide a dynamic incomplete-market hedging strategy for firms to reduce both input and output risk. Toward that, we consider a firm that is concerned with

[1]Luo, R., Fortenbery, T.R., 2016. Corporate Hedging In Incomplete Markets: A Solution Under Price Transmission, 2016 Annual Meeting, July 31-August 2, 2016, Boston, Massachusetts: Agricultural and Applied Economics Association.

eliminating the volatility of its profits. The market is incomplete because the firm cannot take exact offsetting positions to both input and output payoffs, as appropriate futures contracts exist for only one side. The traditional minimum-variance criterion is employed since financial distress resulted from volatile profits is costly for firms (Fok et al., 1997). By taking PT into account, we obtain the minimum-variance hedging policy for the firm, which retains the intuitive elements of classic minimum-variance hedges.

Hedging has been an active topic in derivatives and risk management research for decades. In complete markets without frictions, the classic method is to use static minimum-variance hedges (e.g. Cvitanić and Zapatero, 2004; Duffie, 1989; Hull, 2000; McDonald et al., 2006; Stulz, 2003). Though useful for offsetting risk in the real world, these hedges are suboptimal when hedging in multiple periods (Choudhry, 2003) and do not completely eliminate risks in dynamically complete settings (Basak and Chabakauri, 2012). The alternative is to use dynamic minimum-variance strategies that take into account the time-varying joint distribution of underlies (e.g. Alizadeh et al., 2008; Bertus et al., 2009; Schwartz, 1997) or "Greeks" hedges (e.g. Bakshi et al., 1997; He et al., 2006).

However, when applied in incomplete markets, complete-market hedges may not be optimal in the sense that they do not optimally consider market incompleteness (Basak and Chabakauri, 2012). One standard solution is cross hedges, which use a related futures contract to offset price risk that cannot be hedged directly using available contracts. For example, Ederington (1979) suggests a minimum-variance static hedge when no futures contracts' maturity matches the hedger's time horizon. Wilson (1989) extends the approach of Ederington (1979) and uses soybeans or soybean oil futures to hedge sunflowers positions that do not have futures markets. Bertus et al. (2009) highlight the spread risk between the underlying asset and the specific source of risk and provide a dynamic minimum-variance cross hedging strategy.

In a general incomplete-market setting, Basak and Chabakauri (2012) analyze minimum-variance hedging by incorporating a new parameter for market incompleteness into the standard "Greeks" model. Despite the usefulness of this strategy in the replication and hedge of financial derivatives, it may not be optimal for hedging commodity risk in the sense that commodities do not satisfy the standard no-arbitrage condition (Schwartz, 1997). Gibson and Schwartz (1990), Schwartz (1997), and Schwartz and Smith (2000), among others, suggest that models allowing for stochastic, mean-reverting convenience yields, are necessary to capture the dynamics of commodity prices. Adjusting for instantaneous convenience yield has been also shown to improve risk reduction when hedging commodity risk (e.g. Godbey and Hilliard, 2007). In this paper, we derive the dynamically optimal hedging policy assuming joint diffusion processes for the spot price and a stochastic, mean-reverting convenience yield.

Using the specific case of a hypothetical jet fuel producer that uses light sweet crude oil to produce jet fuel as motivation, we compare performance between the one-sided and two-sided hedging. Markets are incomplete in the sense that only light sweet crude oil futures contracts exist.

Simulations and empirical results show that our two-side model outperforms the one-side strategy.

The contribution of this paper consists of devising a dynamic hedging ratio for firms to jointly offset input and output risk in incomplete markets by incorporating PT mechanism into the traditional complete-market minimizing hedging model. As PT is an important characteristic describing the overall operation of the market (Goodwin and Holt, 1999), this strategy may be practical for firms in multiple industries.

The article proceeds as follows: in section 2, we develop and discuss the optimal hedging policy in incomplete markets; section 3 compares hedging effectiveness of different hedging strategies and section 4 concludes.

2. The Hedging Model

2.1 Minimum-variance hedging in complete markets

Consider a firm that uses *q* units of input to produce the output under current technology utilized. In complete markets, at time 0, the firm buys h_I units of input futures contracts at price f_0^I , and sells at price f_1^I at t =1. The final cost, H_I, for producing 1 unit output is:

$$H_I = I_1 q - \left(f_1^I - f_0^I \right) h_I \qquad (3.1)$$

where I_1 is the spot input price at time 1. At the same time, the firm shorts h_O output futures contracts at price f_0^O. The final income after selling output and its futures contracts at time 2, H_O, is then:

$$H_O = O_2 - \left(f_1^O - f_0^O \right) h_O \tag{3.2}$$

where f_2^O and O_2 are the futures and spot prices of output at time 2, respectively. The expected profit in the presence of transaction costs, Π , is then

$$\Pi = H_O - H_I - m\left(| h_I | + | h_o |\right) \tag{3.3}$$

where $m\left(| h_I | + | h_0 |\right)$ is the proportional brokerage fee, which is assumed to be *m* for each position transacted. The variance-minimizing hedging ratio in complete market is

$$\left(h_I, h_O\right)' = \arg\left\{\min Var\left(\Pi\right)\right\} \ . \tag{3.4}$$

2.2 Minimum-variance hedging in incomplete markets

The futures market is incomplete because futures contracts are limited in kinds, thereby making the common approach in complete market impossible. If futures contracts do not exist for the asset to be hedged, the firm may remain unhedged and therefore exposed to price fluctuations. Alternatively, the firm may choose to mitigate this exposure through another hedging vehicle. In this article, we attempt to help the firm improve the quality of hedging in incomplete markets by accomplishing the price transmission (PT) mechanism between the producer and the consumer prices in the sector of the firm in the traditional variance-minimizing hedge.

In different industries, the PT mechanism is expected to vary in directions and magnitude (e.g. Cramon-Taubadel, 1998; Goodwin and Holt, 1999). According to the direction of PT and the availability of futures contracts, four subcases are considered: (CO) cost-driving PT in which supply forces lead to equilibrium between input and output prices with output futures contracts;

(CI) cost-driving PT with input futures contracts; (DO) demand-driving PT with output futures contracts; (DI) demand-driving PT with input futures contracts. In all cases, the firm may either only hedge cash positions with futures contracts (one-sided hedge) or jointly hedge input and output price risks (two-sided hedge).

Without input futures contract, a CO firm use only output futures to hedge input and output price exposures. The resulting cash flow is

$$\Pi = \left(O_2 - \left(f_2^O - f_0^O\right)h_O^c\right) - I_1 q - m\left|h_O^c\right| \qquad (3.5)$$

where O_t (t = 0,1,2) and I_t (t = 0,1) are spot output and input prices, respectively; f_t^O (t = 0,1,2) is output futures price, and h_O^c is transactions in output futures market. If h_O^c is positive (negative), the firm shorts (longs). Profits Π equal to total income $\left(O_2 - \left(f_2^O - f_0^O\right)h_O^c\right)$ minus expenses for inputs $I_1 q$ and transaction costs $m\left|h_O^c\right|$.

In a widely-applied framework, the PT mechanism for a CO firm could be modeled linearly as

$$O_2 = \theta_0 + \sum_{i=1}^{p}\theta_i O_{2-i} + \sum_{j=1}^{q} b_j I_{2-j} \qquad (3.6)$$

where θ_i and b_j are marginal effects of lagged output and input prices on O_2, respectively. This paper employs the traditional variance-minimizing criterion for the hedger

$$\min_h Var\left(\Pi\right) \qquad (3.7)$$

The effectiveness of two-sided hedge through PT, Eff_{two} , is calculated as $Eff_{two} = -\left(\mathrm{var}\left(\Pi_{two}\right) - \mathrm{var}\left(\Pi_{unhedged}\right)\right)$ and the effectiveness of traditional one-sided hedge is

$Eff_{one} = -\left(\mathrm{var}\left(\Pi_{one}\right) - \mathrm{var}\left(\Pi_{unhedged}\right)\right)$, where Π_{one}, Π_{two}, and $\Pi_{unhedged}$ stands for profits when applying a traditional one-sided hedge, a two-sided PT hedge, and profits of unhedged positions, respectively. The quality-improvement of using the two-sided hedge policy is:

$$G = Eff_{two} - Eff_{one} \tag{3.8}$$

The optimal hedge ratio for a CO firm, h_O^c is then

$$h_O^c = \theta_1\beta_1 - \left(q - b_1\right)\beta_2 \tag{3.9}$$

where $\beta_1 = \dfrac{\mathrm{cov}\left(O, f^O\right)}{\mathrm{var}\left(f^O\right)}$ is the minimizing hedge ratio using output futures to hedge output exposures; and $\beta_2 = \dfrac{\mathrm{cov}\left(I, f^O\right)}{\mathrm{var}\left(f^O\right)}$ is the optimal hedge ratio when cross-hedging input price risk through output futures.

The hedge policy given by (3.9) suggests that since output prices are driven by input price dynamics, the firm may eliminate more risk by a strategy adjusted to PT. The adjusted policy – $\theta_1\beta_1 - \left(q - b_1\right)\beta_2$ – is the weighted average of direct hedge policy β_1 and cross hedge policy β_2. Specifically, the firm sells $\theta_1\beta_1$ for output exposures and buys $\left(q - b_1\right)\beta_2$ for input price risks. For each output cash position, it is optimal to sell β_1 output futures without considering for the input price risks. When jointly hedge input and output risks in a PT framework, the short position is adjusted to $\theta_1\beta_1$ because product price at time 2 is affected by its price at time 1. θ_1 gauges the magnitude of this lagged-price effect. The greater is θ_1, the stronger is the autocorrelation in output price series, and the higher is the weight for β_1 to hedge output price exposures.

As for input price exposures, the firm uses $-\left(q-b_1\right)\beta_2$ (i.e. longs $\left(q-b_1\right)\beta_2$) output futures positions. More specifically, the optimal cross hedge for each input cash position is β_2. When not accounting for cost-driving PT, the firm could use $-q\beta_2$ output futures positions to cross hedge input price exposure since the firm has a constant input-output ratio of *q*. However, cost driving indicates that product prices are affected by lagged prices of raw materials, this mechanism therefore provides "natural hedge" to output price fluctuations, ending in a deduction of $b_1\beta_2$ in long positions. b_1 is the magnitude of PT and measures the marginal output price effect of lagged input price. The greater is b_1, the less the firm has to short output futures positions.

Similarly, for CI firms with cost-driving PT and input futures market, the problem is that

$$\begin{aligned} &\min_{h_I^c}\left\{Var\left(\Pi\right)\right\} \\ &s.t. \\ &\qquad O_2=\theta_0+\sum_{i=1}^{p}\theta_i O_{2-i}+\sum_{j=1}^{q}b_j I_{2-j} \\ &\qquad \Pi=O_2-\left(I_1 q-\left(f_1^I-f_0^I\right)h_I^c\right)-m\left|h_I^c\right| \end{aligned} \tag{3.10}$$

where f_1^I is input futures prices. h_I^c is input futures positions and positive (negative) h_I^c indicates buying (selling) input futures. Solving Eq. (3.10) yields

$$h_I^c=-\theta_1\beta_2+(q-b_1)\beta_1\ , \tag{3.11}$$

where $\beta_1=\dfrac{\operatorname{cov}\left(I,f^I\right)}{\operatorname{var}\left(f^I\right)}$ is the minimizing β-ratio between futures and the underlying or the optimal one-side input hedge ratio; and $\beta_2=\dfrac{\operatorname{cov}\left(O,f^I\right)}{\operatorname{var}\left(f^I\right)}$ is the optimal hedge ratio when cross-hedging output price risk through input futures. The minimum-variance hedge strategy adjusted is again the weighted average of β_1 and β_2.

For demand-driving cases (DO) and (DI) in which major buyers play the price leadership roles, price transmission suggests that

$$I_1 = \chi_0 + \sum_{i=1}^{s} \chi_i I_{1-i} + \sum_{j=1}^{k} d_j O_{1-j} \tag{3.12}$$

where χ_i is the input price effect of its lags and d_j measures the impact of lagged output price on input prices.

Due to the absence of available input futures contracts, a DO firm's problem using output futures contract is

$$\begin{aligned} &\min_{h_O^d} \left\{ Var\left(\Pi \right) \right\} \\ &s.t. \\ &\qquad I_1 = \chi_0 + \sum_{i=1}^{s} \chi_i I_{1-i} + \sum_{j=1}^{k} d_j O_{1-j} \\ &\quad \Pi = \left(O_2 - \left(f_2^O - f_0^O \right) h_O^d \right) - I_1 q - m \left| h_O^d \right| \end{aligned} \tag{3.13}$$

The optimal ratio is then

$$h_O^d = \beta_1 \tag{3.14}$$

which is positive when selling output futures. h_O^d is the same as the one-side hedge solution. The reason is that under demand-driving price links, input price at time 1 is associated with the time-0 price of output and its own. It follows that the only exposure a DO-firm facing is output price at time 2.

For a DI company with input futures available, its problem is

$$\min_{h_I^d} \left\{ Var\left(\Pi \right) \right\}$$
$$s.t.$$
$$I_1 = \chi_0 + \sum_{i=1}^{s} \chi_i I_{1-i} + \sum_{j=1}^{k} d_j O_{1-j} \qquad (3.15)$$
$$\Pi = O_2 - \left(I_1 q - \left(f_1^I - f_0^I \right) h_I^d \right) - m \left| h_I^d \right|$$

and the solution is

$$h_I^d = -\beta_2 \qquad (3.16)$$

where h_I^d is the optimal input futures positions to buy and a positive h_I^d suggests to long input futures. With the presence of price transmissions, the adjusted minimizing-variance strategy for the DI firm is to cross hedge output price risks through shorting β_2 input futures. This is because dynamics of input prices at time 1 are driven by output prices at time 0, making output exposure to be the problem to handle with.

2.3 Economic Setup and dynamic hedging policy

In this economy, we follow Gibson and Schwartz (1990), Schwartz (1997) and others and employ the two-factor model to describe price dynamics. Assume that the spot price S_t and convenience yield δ_t follow a two-factor diffusion model:

$$\begin{aligned} dS_t &= \left(\mu - \delta_t \right) S_t dt + \sigma_s S_t dZ_S \\ d\delta_t &= \kappa_\delta \left(\alpha_\delta - \delta_t \right) dt + \sigma_\delta dZ_\delta \end{aligned}, \qquad (3.17)$$

where the stochastic mean, μ, convenience yield, δ_t, and volatility σ_S, are deterministic parameters of S_t. The dynamics of inconvenience yield is captured by the speed adjustment parameter, κ_δ, the average long run convenience yield α_δ, and the volatility σ_δ. dZ_S and dZ_δ

are standard Wiener processes, and $dZ_\delta = \rho_{S,\delta} dZ_S$, where $\rho_{S,\delta}$ is the correlation coefficient between the two processes.

For hedging horizon [0, *T*], the dynamics for the futures price, F, is modeled as

$$F_t = F\left(S_t, \delta_{t,}, t\right) = S_t A(T-t) e^{r(T-t) - H_\delta(T-t)\delta_t} \quad , \tag{3.18}$$

where *r* denotes the short-term risk-free rate,

$$A(T) = \exp\left(\frac{\left(H_\delta(T) - T\right)\left(\kappa_\delta^2 \alpha_\delta - \kappa_\delta \lambda_\delta \sigma_\delta - \frac{1}{2}\sigma_\delta^2 + \rho_{s,\delta}\sigma_s \sigma_\delta \kappa_\delta\right)}{\kappa_\delta^2} - \frac{\sigma_\delta^2 H_\delta^2(T)}{4\kappa_\delta} \right), \tag{3.19}$$

λ_δ is the market price of risk for the convenience yield[2], and $H_\delta(T) = \frac{\left(1 - e^{-\kappa_\delta T}\right)}{\kappa_\delta}$.

The hedger chooses a direct minimum-variance hedging policy, β_1, as

$$\begin{aligned} \beta_1 &= \frac{Cov\left(S_t, F_t\right)}{Var\left(F_t\right)} \\ &= \frac{Cov\left(S_t, S_t A(T-t) e^{r(T-t) - H_\delta(T-t)\delta_t}\right)}{\left(A(T-t) e^{r(T-t)}\right)^2 Var\left(S_t e^{-H_\delta(T-t)\delta_t}\right)} \end{aligned} \quad . \tag{3.20}$$

Substituting (3.19) into (3.20) yields

$$\begin{aligned} \beta_1 &= \frac{e^{-r(T-t) + \delta_0 e^{-\kappa\delta t} + \alpha_\delta\left(1 - e^{-\kappa\delta t}\right)} Cov\left(e^{\ln w_t}, e^{\ln u_t}\right)}{A(T-t) Var\left(e^{\ln u_t}\right)} \\ &= \frac{e^{-r(T-t) + \delta_0 e^{-\kappa\delta t} + \alpha_\delta\left(1 - e^{-\kappa\delta t}\right)} e^{\mu_w - \mu_u + \frac{1}{2}\left(\sigma_w^2 - \sigma_u^2\right)} \left(e^{\sigma_{wu}} - 1\right)}{A(T-t)\left(e^{\sigma_u^2} - 1\right)}, \end{aligned} \tag{3.21}$$

[2] See Gibson and Schwartz (1990) and Schwartz (1997).

where $u_t = S_t e^{-H_\delta(T-t)\delta_t}$ and $w_t = S_t e^{\sigma_\delta e^{-\kappa_\delta t}\int_0^t e^{\kappa_\delta v} dZ_\delta^*(v)}$. μ_u is the expectation of $\ln u_t$, σ_u^2 is the volatility of $\ln u_t$. μ_w and σ_w^2 are the expectation and volatility of $\ln w_t$, respectively. σ_{wu} represents covariance between $\ln w_t$ and $\ln u_t$. The direct hedge, β_1 , is comprised of the diffusion parameters of spot price S_t , convenience yield δ_t , and futures price F_t (see Appendix 3.B).

Following Bertus et al. (2009), we postulate the relationship between spot prices of asset with and without futures contracts (denoted by S_t and P_t , respectively) to be

$$P_t = S_t e^{c_t} \quad . \tag{3.22}$$

c_t is the log spread and follows the dynamics

$$dc_t = \kappa_c \left(\alpha_c - c_t\right) dt + \sigma_c dZ_c \quad , \tag{3.23}$$

where the average long run spread α_c , the speed adjustment parameter κ_c , and the volatility σ_c are deterministic parameters. $dZ_c = \rho_{s,c} dZ_s$ is the increment of a standard Winer process, and $dZ_\delta = \rho_{c,\delta} dZ_c$.

The cross-hedging ratio according to variance-minimizing criterion, β_2 , is then

$$\begin{aligned} \beta_2 &= \frac{Cov\left(P_t, F_t\right)}{Var\left(F_t\right)} \\ &= \frac{Cov\left(Se^{c_t}, S_t A\left(T-t\right) e^{r(T-t) - H_\delta(T-t)\delta_t}\right)}{\left(A\left(T-t\right) e^{r(T-t)}\right)^2 Var\left(S_t e^{-H_\delta(T-t)\delta_t}\right)} \quad . \end{aligned} \tag{3.24}$$

Equivalently,

$$
\begin{aligned}
\beta_2 &= \frac{e^{-r(T-t)+c_0 e^{-\kappa_c t}+\alpha_c\left(1-e^{-\kappa_c t}\right)} Cov\left(y_t, x_t\right)}{A(T-t) Var\left(x_t\right)} \\
&= \frac{e^{-r(T-t)+c_0 e^{-\kappa_c t}+\alpha_c\left(1-e^{-\kappa_c t}\right)} e^{\mu_y-\mu_x+\frac{1}{2}\left(\sigma_y^2-\sigma_x^2\right)}\left(e^{\sigma_{xy}}-1\right)}{A(T-t)\left(e^{\sigma_x^2}-1\right)} .
\end{aligned} \tag{3.25}
$$

where $x_t = S_t e^{-H_\delta(T-t)\delta_t}$ and $y_t = S_t e^{\sigma_c e^{-\kappa_c t}\int_0^t e^{-\kappa_c v} dZ_c}$. μ_x is the expectation of $\ln x_t$, σ_x^2 is the volatility of $\ln x_t$. μ_y and σ_y^2 are the expectation and volatility of $\ln y_t$, respectively. σ_{xy} stands for covariance between $\ln y_t$ and $\ln x_t$. The cross hedging ratio, β_2 , is comprised of parameters in the dynamics of spot price S_t, convenience yield δ_t, futures price F_t and of the spread c_t (see Appendix 3.C).

3. Comparisons of Hedging Models

This section aims to compare performance between the one-sided and two-sided hedges in incomplete markets. More specific, we consider a hypothetical firm that uses light sweet crude oil to produce jet fuel. The firm intends to reduce price exposures with a futures contract on light sweet crude oil (the input).

3.1 Data

The data used to test the models consist of weekly observations in the period from April 4, 1990 to August 16, 2015. Two futures contracts for light sweet crude oil for delivery to Cushing, OK, spot prices for New York Harbor jet fuel, and spot price for light sweet crude oil are obtained from the Energy Information Administration. Table 3.1 describes the price data used, including the contract closest to maturity F1 and the third contract closest to maturity F3.

3.2 Parameter Estimation for the two-factor model

Following Schwartz (1997), we use the Kalman filtering methodology to obtain the parameter estimation for the two-factor diffusion model. The estimation uses contracts F1 and F3. The time to maturity of F1 is denoted by T_1 and T_3 is the time to maturity of F3. P_t is the price for jet fuel. By writing the joint diffusion of the two-factor model in state space form, we have the measurement equation to be (Bertus et al., 2009):

$$y_t = Z_t \alpha_t + d_t + \eta_t, t = 1, ..., T \tag{3.26}$$

where

$$y_t = \ln\left[\ln\left(F1_t\right), \ln\left(F3_t\right), P_t\right]'$$
$$Z_t = \begin{bmatrix} 1 & -H\left(T_1\right) & 0 \\ 1 & -H\left(T_3\right) & 0 \\ 1 & 0 & 1 \end{bmatrix} .$$
$$d_1 = \left[\ln\left(A\left(T_1\right)\right) + rT_1 \quad \ln\left(A\left(T_3\right)\right) + rT_3 \quad 0\right]'$$
$$\alpha_t = \left[\ln\left(S_t\right) \quad \delta_t \quad c_t\right]'$$

η_t is a 3×1 vector of serially uncorrelated disturbances with $E\left(\eta_t\right) = 0$ and $\operatorname{var}\left(\eta_t\right) = H_t$. Parameter estimations are given in Table 3.2.

3.3 Estimation of PT Parameters

Estimation based on a vector autoregression (VAR) model is used to describe the PT mechanism for this jet fuel producer because a VAR model features the structure that each variable is a linear function of its own past lags and lags of other time series variables. Specifically, we use the following VAR model to estimate the direction and magnitude of PT:

$$\begin{aligned} I_t &= \chi_0 + \chi_1 I_{t-1} + d_1 O_{t-1} + \varepsilon_{1t} \\ O_t &= \theta_0 + b_1 I_{t-1} + \theta_1 O_{t-1} + \varepsilon_{2t} \end{aligned} \tag{3.27}$$

where I_t is the log spot price of input, or the log spot price of the light sweet crude oil; and O_t stands for the log spot price of output, i.e., the price of jet fuel. $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are error terms. All price time series pass the integration test.

Estimation results for the VAR model is reported in Table 3.3. As is shown, PT parameter estimates in both equations are statistically significant, suggesting that the evolution of output (input) price statistically depends on its own lags and the lags of the input (output) price. These results capture the linear interdependencies among input and output price series and therefore indicate the existence of price transmission.

The identification of the direction of PT mechanism is based on the sign of $b_1(d_1)$, which estimates the impact of current output (input) price on the future input (output) price. The positive effect of lagged input price on output price (b_1) suggests that the change in output price is driven by the fluctuation of lagged input price, since increases in current input price could result in increase in the next-period output price. The estimate of d_1, however, is negative, indicating that when current output price increases, future input price tends to decrease. Thus, the direction of PT for this jet fuel producer is *cost driving* in the sense that current output price is *positively* affected by lagged input price. Since the available futures contracts are only written on the input (futures for light sweet crude oil), we categorize the hedging problem of the jet fuel produce as CI case, i.e., cost-driving PT with input futures contracts.

3.4 Comparisons of hedging policy and hedging effectiveness

Based on the parameter values reported in Table 3.2 and Table 3.3, we compute the direct and cross hedging ratio β_1 and β_2. The optimal two-sided hedge policy for the CI firm , h_I^c, is then calculated via Eq. (3.11). Since the CI firm only has available futures contracts for inputs, its one-sided hedge policy is

$$h_{I,one-sided}^c = q\beta_1 \ , \tag{3.28}$$

and positive $h_{I,one-sided}^c$ corresponds to long positions. The effectiveness of the two-sided model, Eff_{two}, is calculated as $Eff_{two} = -\left(\text{var}\left(\Pi_{two}\right) - \text{var}\left(\Pi_{unhedged}\right)\right)$ and the effectiveness of the one-sided model is $Eff_{one} = -\left(\text{var}\left(\Pi_{one}\right) - \text{var}\left(\Pi_{unhedged}\right)\right)$, where Π_{one} , Π_{two}, and $\Pi_{unhedged}$ stand for profits under one-sided model, two-sided model and unhedged positions, respectively.

Table 3.4 gives the results for the comparison. We report hedging policy and hedging effectiveness for each model under four horizons from 4 weeks up to two years. The hedges are not adjusted during the horizon. Panel A depicts results from matching horizons. However, the matching cases are almost impossible in real-world applications, as the last trading day of crude oil futures is the third business day prior to the 25th calendar day of the month preceding the delivery month. We follow Bertus et al. (2009) and assume that the hedge horizon is two weeks shorter than the futures expiration. We report the results for the unmatched case in Panel B.

For the matched cases (Panel A of Table 3.4), the two-sided hedging policy ranges from 0.1599 (two years) to 86.4184 (4 weeks), and is greater than policy of the one-sided model in each case. The effectiveness of the two-sided model ranges from 0.0013 (two years) to 15.5523 (4 weeks); while the one-sided effectiveness ranges from 0.0011 (two years) to 12.3592 (4 weeks). For every horizon, the two-sided model outperforms the traditional one-sided model.

Panel B of Table 3.4 presents comparison results when futures expire two weeks later the expiration of hedge. We find that the effectiveness of unmatched cases using our two-sided model remains qualitatively the same as that of the matching horizons. Similar to Panel A, the two-sided model has greater effectiveness than the one-sided hedge for all horizons in Panel B.

4. Conclusions

Futures contracts are only written on a limited number of assets, thereby making futures markets incomplete for many firms. By directly accounting for price transmission between the input and the output, this paper develops an incomplete-market hedging strategy through which a firm may minimize both input and output price fluctuations through a single usable input/output futures contract even in incomplete market. This strategy is conditional on the direction and magnitude of price transactions between raw materials and products, as well as on the availability of futures market. The optimal hedge ratio is the weighted average of the classic minimizing strategy of direct hedging ratio, and the cross hedging policy.

We apply our model to a hypothetical jet fuel producer who used crude oil to produce jet fuel, and compare hedging ratios and performance between a traditional one-sided hedge and our two-sided strategy. We find that the two-sided model results in a more effective hedge. These findings thus suggest that jet fuel producers may reduce more profit fluctuations by using a hedging model that directly accounts for movements of both the input and output prices. Meanwhile, since price transmission is evidenced over many supply chains, the two-sided hedging policy we proposed could be employed by many firms in multiple industries in their incomplete-market risk management applications.

Appendix 3.A Solution to the Hedging Model

The problem a CI firm with cost-driving PT and input futures market is

$$\min_{h_O^c}\left\{Var\left(\Pi\right)\right\}$$

$$s.t.\quad \begin{aligned} O_2 &= \theta_0 + \sum_{i=1}^{p}\theta_i O_{2-i} + \sum_{j=1}^{q} b_j I_{2-j} \\ \Pi &= \left(O_2 - \left(f_2^O - f_0^O\right)h_O^c\right) - I_1 q - m\left|h_O^c\right| \end{aligned} \quad . \tag{3.29}$$

The variance of profits Π thus is

$$\begin{aligned} Var\left(\Pi\right) &= \theta_1^2 Var\left(O\right) + h_O^{c^2} Var\left(f^O\right) + \left(b_1 - q\right)^2 Var\left(I_1\right) \\ &+ \theta_1 h_O^c Cov\left(O, f^O\right) + \theta_1\left(b_1 - q\right)Cov\left(O, I\right) + h_O^c\left(b_1 - q\right)Cov\left(f^O, I\right) \end{aligned} \tag{3.30}$$

Solving (3.29) yield

$$h_O^c = \theta_1 \frac{\text{cov}\left(O, f^O\right)}{\text{var}\left(f^O\right)} - \left(q - b_1\right)\frac{\text{cov}\left(I, f^O\right)}{\text{var}\left(f^O\right)} \tag{3.31}$$

Defining $\beta_1 = \dfrac{\text{cov}\left(O, f^O\right)}{\text{var}\left(f^O\right)}$ and $\beta_2 = \dfrac{\text{cov}\left(I, f^O\right)}{\text{var}\left(f^O\right)}$, we have (3.9). Solutions to h_I^c, h_O^d, and h_I^d can be derived via similar procedures.

Appendix 3.B Solution to the Direct Hedging Ratio

The hedger chooses a direct minimum-variance hedging policy, β_1, as

$$\begin{aligned}\beta_1 &= \frac{Cov\left(S_t, F_t\right)}{Var\left(F_t\right)} \\ &= \frac{Cov\left(S_t, S_t A\left(T-t\right) e^{r\left(T-t\right)-H_\delta\left(T-t\right)\delta_t}\right)}{\left(A\left(T-t\right)e^{r\left(T-t\right)}\right)^2 Var\left(S_t e^{-H_\delta\left(T-t\right)\delta_t}\right)}\end{aligned}, \qquad (3.32)$$

or

$$\begin{aligned}\beta_1 &= \frac{e^{-r\left(T-t\right)+\delta_0 e^{-\kappa_\delta t}+\alpha_\delta\left(1-e^{-\kappa_\delta t}\right)} Cov\left(e^{\ln w_t}, e^{\ln u_t}\right)}{A\left(T-t\right) Var\left(e^{\ln u_t}\right)} \\ &= \frac{e^{-r\left(T-t\right)+\delta_0 e^{-\kappa_\delta t}+\alpha_\delta\left(1-e^{-\kappa_\delta t}\right)} e^{\mu_w-\mu_u+\frac{1}{2}\left(\sigma_w^2-\sigma_u^2\right)}\left(e^{\sigma_{wu}}-1\right)}{A\left(T-t\right)\left(e^{\sigma_u^2}-1\right)},\end{aligned} \qquad (3.33)$$

where $u_t = S_t e^{-H_\delta\left(T-t\right)\delta_t}$ and $w_t = S_t e^{\sigma_\delta e^{-\kappa_\delta t}\int_0^t e^{\kappa_\delta v} dZ_\delta^*(v)}$. Gibson and Schwartz (1990) and Schwartz (1997), among others, have shown that the expectation of $\ln u_t$, μ_t is

$$\begin{aligned}\mu_u \equiv E\left[\ln u_t\right] &= E\left[\ln S_t\right] - \int_0^t\left(\delta_0 e^{-\kappa_\delta t}+\alpha_\delta\left(1-e^{-\kappa_\delta t}\right)\right)dt + H_\delta\left(T-t\right)E\left(\delta_t\right) \\ &= \ln S_0 + \left(\mu - \frac{1}{2}\sigma_s^2\right)t - H_\delta\left(t\right)\left(\alpha_\delta-\delta_0\right)\delta - \alpha_\delta t \\ &\quad - H_\delta\left(T-t\right)\left(\delta_0 e^{-\kappa_\delta t} + H_\delta\left(t\right)\alpha_\delta\kappa_\delta\right)\end{aligned}, \qquad (3.34)$$

and the volatility of $\ln u_t$, σ_u^2 is

$$\begin{aligned}\sigma_u^2 &\equiv Var\left[\ln u_t\right] \\ &= Var\left[\ln S_t\right] + H_\delta^2\left(T-t\right)\left(\frac{\sigma_\delta^2}{2\kappa_\delta}\left(1-e^{-2\kappa_\delta t}\right)\right) \\ &\quad - 2H_\delta\left(T-t\right)\left(\rho_{s,\delta}\sigma_\delta\sigma_s H_\delta\left(t\right) - \frac{1}{2}\sigma_\delta^2 H_\delta^2\left(t\right)\right)\end{aligned}, \qquad (3.35)$$

where

$$Var\left[\ln S_t\right] = -\left(H_\delta\left(t\right)-t\right)\frac{\sigma_\delta^2}{\kappa_\delta^2} - \left(\frac{\sigma_\delta^2}{2\kappa_\delta}H_\delta^2\left(t\right)\right) + \sigma_s^2 t + 2\frac{\rho_{s,\delta}\sigma_s\sigma_\delta}{\kappa_\delta}\left(H_\delta\left(t\right)-t\right) \tag{3.36}$$

The expectation of $\ln w_t$, μ_w , is

$$\begin{aligned}\mu_w &\equiv E\left[\ln w_t\right] \\ &= \ln S_0 + \left(\mu - \frac{1}{2}\sigma_s^2\right)t + H_\delta\left(t\right)\left(\alpha_\delta - \delta_0\right) - \alpha_\delta t\end{aligned}, \tag{3.37}$$

and its variance σ_w^2 , is

$$\begin{aligned}\sigma_w^2 &\equiv Var\left[\ln w_t\right] \\ &= Var\left[\ln S_t\right] + \sigma_\delta^2\left(\frac{1-e^{-2\kappa_\delta t}}{2\kappa_\delta}\right) \\ &-\sigma_\delta^2 H_\delta^2\left(t\right) + 2\rho_{s,\delta}\sigma_s\sigma_\delta H_\delta\left(t\right)\end{aligned}. \tag{3.38}$$

Covariance between u_t and w_t , σ_{uw} , is

$$\begin{aligned}\sigma_{uw} &\equiv Cov\left(\ln u_t, \ln w_t\right) \\ &= Var\left[\ln S_t\right] - \frac{1}{2}\sigma_\delta^2 H_\delta^2\left(t\right) \\ &- \ H_\delta\left(T-t\right)\left(\rho_{s,\delta}\sigma_s\sigma_\delta H_\delta\left(t\right) - \frac{1}{2}\sigma_\delta^2 H_\delta^2\left(t\right)\right) \\ &+ \ \rho_{s,\delta}\sigma_s\sigma_\delta H_\delta\left(t\right) \\ &- \ H_\delta\left(T-t\right)\sigma_\delta^2\left(\frac{1-e^{-2\kappa_\delta t}}{2\kappa_\delta}\right)\end{aligned}. \tag{3.39}$$

Plugging (3.34)-(3.39) into (3.21) yields β_1.

Appendix 3.C Solution to the Cross-hedging Ratio

The cross-hedging ratio according to variance-minimizing criterion, β_2, is

$$\begin{aligned}\beta_2 &= \frac{Cov(P_t, F_t)}{Var(F_t)} \\ &= \frac{Cov\left(Se^{c_t}, S_t A(T-t) e^{r(T-t)-H_\delta(T-t)\delta_t}\right)}{\left(A(T-t)e^{r(T-t)}\right)^2 Var\left(S_t e^{-H_\delta(T-t)\delta_t}\right)}\end{aligned}, \qquad (3.40)$$

or,

$$\begin{aligned}\beta_2 &= \frac{e^{-r(T-t)+c_0 e^{-\kappa_c t}+\alpha_c\left(1-e^{-\kappa_c t}\right)} Cov(y_t, x_t)}{A(T-t) Var(x_t)} \\ &= \frac{e^{-r(T-t)+c_0 e^{-\kappa_c t}+\alpha_c\left(1-e^{-\kappa_c t}\right)} e^{\mu_y-\mu_x+\frac{1}{2}\left(\sigma_y^2-\sigma_x^2\right)}\left(e^{\sigma_{xy}}-1\right)}{A(T-t)\left(e^{\sigma_x^2}-1\right)}\end{aligned}. \qquad (3.41)$$

where $x_t = S_t e^{-H_\delta(T-t)\delta_t}$ and $y_t = S_t e^{\sigma_c e^{-\kappa_c t}\int_0^t e^{-\kappa_c v} dZ_c}$. Bertus et al. (2009) show that the expectation and volatility of $\ln x_t$ and $\ln y_t$ are

$$\begin{aligned}\mu_x &\equiv E[\ln x_t] = \ln S_0 + \left(\mu - \frac{1}{2}\sigma_s^2\right)t - H_\delta(t)(\alpha_\delta - \delta_0)\delta - \alpha_\delta t \\ &\qquad - H_\delta(T-t)\left(\delta_0 e^{-\kappa_\delta t} + H_\delta(t)\alpha_\delta\kappa_\delta\right) \\ \sigma_x^2 &\equiv Var[\ln x_t] \\ &= Var[\ln S_t] + H_c^2(T-t)\left(\frac{\sigma_\delta^2}{2\kappa_\delta}\left(1-e^{-2\kappa_\delta t}\right)\right) \\ &\quad - 2H_c(T-t)\left(\rho_{s,\delta}\sigma_\delta\sigma_s H_\delta(t) - \frac{1}{2}\sigma_\delta^2 H_\delta^2(t)\right) \\ \mu_y &\equiv E[\ln y_t] = \ln S_0 + \left(\mu - \frac{1}{2}\sigma_s^2\right)t + H_\delta(t)(\alpha_\delta - \delta_0) - \alpha_\delta t \\ \sigma_y^2 &\equiv Var[\ln y_t] = Var[\ln S_t] + \sigma_c^2\left(\frac{1-e^{-2\kappa_c t}}{2\kappa_c}\right) \\ &\qquad + 2\left(\frac{\sigma_s\sigma_c\rho_{\delta c}}{\kappa_\delta+\kappa_c}\left(H_\delta(t)e^{-\kappa_c t} - H_c(t)\right) + \rho_{sc}\sigma_s\sigma_c H_c(t)\right)\end{aligned}, \qquad (3.42)$$

where $H_c(t) = \left(1-e^{\kappa_\delta t}\right)/\kappa_c$. Covariance between $\ln x_t$ and $\ln y_t$ is

$$
\begin{aligned}
\sigma_{x,y} \equiv \mathrm{Cov}\left[\ln x_t, \ln y_t\right] = \mathrm{Var}\left[\ln S_t\right] \\
&+ \frac{\rho_{c,\delta}\sigma_c\sigma_\delta}{\kappa_c + \kappa_\delta}\left(H_\delta(t)e^{-\kappa_c t} - H_c(t)\right) \\
&- H_c(T-t)\left[\rho_{s\delta}\sigma_\delta\sigma_S H_\delta(t) - \frac{1}{2}\sigma_\delta^2 H_\delta^2(t)\right] \\
&+ \rho_{s,c}\sigma_s\sigma_c\frac{1-e^{-\kappa_c t}}{\kappa_c} \\
&- H_c(T-t)\left(\rho_{c\delta}\sigma_\delta\sigma_c\left(\frac{1-e^{-t(\kappa_\delta+\kappa_c)}}{\kappa_\delta+\kappa_c}\right)\right)
\end{aligned} \tag{3.43}
$$

Plugging (3.42)-(3.43) into (3.25) yields β_2.

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Table 3.1 Futures and Spot Price Data

	Mean Price (Standard Error)	Mean Maturity (Standard Error)
Futures Contract: F1	47.15 (0.868)	0.042 (0.245) years
Futures Contract: F3	47.33 (0.876)	0.209 (0.248)
Jet fuel	1.37 (0.027)	
Light Sweet Crude Oil	47.15 (0.868)	

This table presents data description. The data consist of weekly observations in the period from April 4, 1990 to August 16, 2015, including two futures contracts for light sweet crude oil for delivery to Cushing, OK (F1 and F3, where F1 is the contract closest to maturity and F3 is the third contract closest to maturity.), spot prices for New York Harbor jet fuel, and spot price for light sweet crude oil. All data are obtained from the Energy Information Administration.

Table 3.2 Parameter Estimates for The Two-Factor Diffusion Model

Parameter	Estimates
α_δ	0.5031
κ_δ	1.0427
σ_δ	0.2681
σ_s	0.5040
$\rho_{S\delta}$	0.1500
λ_δ	0.4893
α_c	0.4997
κ_c	4.0238
σ_c	0.4825
ρ_{Sc}	0.5322
$\rho_{c\delta}$	0.3987

This table presents the Kalman filter parameter estimates for the two-factor diffusion model. Parameters are estimated using weekly data from April 4, 1990 to August 16, 2015. Futures prices for light sweet crude oil for delivery to Cushing, OK, and spot prices for New York Harbor jet fuel are obtained from the Energy Information Administration.

Table 3.3 Estimation Results for the PT Mechanism

Parameter	**Estimate (Std. Error)**
Equation: $I_t = \chi_0 + \chi_1 I_{t-1} + d_1 O_{t-1} + \varepsilon_{1t}$	
χ_1	1.2778*** (0.2468)
d_1	-1.3185*** (0.2346)
χ_0	-0.9171 (0.8797)
Adjusted R-squared	0.03195
Equation: $O_t = \theta_0 + b_1 I_{t-1} + \theta_1 O_{t-1} + \varepsilon_{2t}$	
b_1	1.2443***(0.2609)
θ_1	-1.2565***(0.2480)
θ_0	-4.3598***(0.9300)
Adjusted R-squared	0.02201
Num. of Observations	1306

This table presents the parameter estimation for the PT mechanism. We use the vector autoregression (VAR) model to describe interdependencies between input and output price time series. The VAR model has the following structure:

$$I_t = \chi_0 + \chi_1 I_{t-1} + d_1 O_{t-1} + \varepsilon_{1t}$$

$$O_t = \theta_0 + b_1 I_{t-1} + \theta_1 O_{t-1} + \varepsilon_{2t}$$

where I_t is the log spot price of input, or the log spot price of the light sweet crude oil; and O_t stands for the log spot price of output, i.e., the price of jet fuel. ε_{1t} and ε_{2t} are error terms. All price time series pass the integration test. Significance codes: <0.0001 '***', 0.01 '**', 0.1'*'.

Table 3.4 Comparions of Hedging Models

Horizon	Hedging Policy		Effectiveness	
Panel A: Futures expiration matches hedging horizon				
	Two-sided	One-sided	Two-sided	One-sided
4 weeks	86.4184	47.2607	15.5523	12.3592
13 weeks	20.9923	11.3716	2.8846	2.2787
26 weeks	7.1514	3.8739	0.6653	0.5256
One year	1.0408	1.6443	0.8907	0.0701
Two years	0.1599	0.0866	0.0013	0.0011
Panel B: Futures expiration is two weeks longer than hedging horizon				
	Two-sided	One-sided	Two-sided	One-sided
4 weeks	55.2736	29.9775	9.3698	7.4074
13 weeks	17.1626	9.2970	2.2210	1.7545
26 weeks	6.2567	3.3893	0.5482	0.4331
One year	1.4914	0.8079	0.0599	0.0473
Two years	0.1478	0.0800	0.0012	0.0001

This table presents the hedging performance for the one-sided and two-sided model. We report hedging policy and hedging effectiveness for each model under four horizons from 4 weeks up to two years. The hedges are not adjusted during the horizon. The optimal two-sided hedge policy for the CI firm is $h_I^c = (q - b_1)\beta_1 - \theta_1\beta_2$ and the one-sided hedge policy is $h_{I,one-sided}^c = q\beta_1$. Effectiveness of the two-sided and one-sided models are $Eff_{two} = -\left(\text{var}(\Pi_{two}) - \text{var}(\Pi_{unhedged})\right)$ and $Eff_{one} = -\left(\text{var}(\Pi_{one}) - \text{var}(\Pi_{unhedged})\right)$, respectively. Π_{one} , Π_{two} , and $\Pi_{unhedged}$ stand for profits under one-sided model, two-sided model and unhedged positions, respectively.