ESSAYS IN DYNAMIC CORPORATE FINANCE

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Abstract

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This dissertation consists of two essays on dynamic models in corporate finance. In the first essay, I estimate a dynamic investment model for business groups in which their pyramidal ownership structure generates an agency problem between controlling and minority shareholders. In the model, the controlling shareholder can transfer resources across group firms using intra-group loans, allowing risk sharing and reducing the need for external financing. In a sample of Chilean business groups, I perform counterfactual experiments in which I compare group-affiliated firms with equivalent non-group firms. I find that for the average business group the incremental value of the internal capital market represents roughly 1.5–1.7% of the firm equity value. Although the controlling shareholder gets a larger portion of the value gains, minority shareholders also benefit from these internal transactions.

In the second essay, we estimate a structural model of investment for a firm exposed to output price risk, which can be hedged using derivatives. In our model, we endogenize the cost of debt, which is affected by the firm's risk management policies. Hedging, therefore, creates value for the company by reducing the cost of debt. Additionally, since hedging has the effect of reducing the variability of the cash flows generated by the firm, it also creates value by exploiting convex costs and concave payoffs in our model. Using a dataset with detailed information on the derivative positions of upstream oil and gas firms during 1996–2013, we estimate the model via the simulated method of moments (SMM). We estimate that the value of hedging is 7.67% of assets. Roughly, half of this value is a result of the effect of hedging on the cost of debt, the rest of the value being related with other non-linearities in the model. Comparative statics exercises suggest that the variables that most affect hedging policies are the volatility of internal cash flows, capital adjustment costs, costs of equity financing, and the risk

premium/discount in the derivatives market. Consequently, the value created by hedging is also most sensitive to these variables, and especially to the cost of equity financing and the risk premium/discount in the derivatives market.

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Chapter 1

The value of the internal capital markets of business groups: Evidence from a structural estimation

1.1 Introduction

Business groups –sets of independent firms controlled by a common shareholder– are a common corporate structure in many developed and emerging economies (La Porta et al., 1999). Similar to U.S. multisegment firms (conglomerates), business groups benefit from their ability to operate internal capital markets, which allow them to redistribute resources among their members. The literature identifies bright and dark sides of internal capital markets of business groups. On the bright side, it is argued that internal capital markets help to overcome difficulties in accessing external financial markets (Khanna and Palepu, 2000; Khanna and Yafeh, 2005). On the dark side there is inefficient capital allocation and agency problems (Scharfstein and Stein, 2000; Claessens et al., 2002). There is empirical evidence supporting both sides, which suggests that both effects are likely to work simultaneously. Which effect dominates the other, however, remains an open question.

The usual way to address this question is by comparing performance and market valuations of affiliated firms with non-group firms (e.g., Shin and Park, 1999; Khanna and Palepu, 2000; Khanna and Yafeh, 2005). This, however, is sometimes empirically problematic. First, non-group firms may not be the right benchmark to compare affiliated firms, as they could be fundamentally different. Second, most of the variables in the data, such as investment, external and internal financing, and dividend distributions are endogenously chosen, and exogenous shocks to ensure causality are hard to find. Lastly, it is difficult to estimate underlying quantities that determine the behavior of firms, such as costs of financing, adjustment costs, and parameters governing a firm's productivity process. Recently, the literature has made progress addressing these problems by exploiting quasi-natural experiments and estimators that better deal with endogeneity (e.g., Almeida et al., 2015).

In this paper, I propose an alternative method to explore this question using structural estimation, which identifies the parameters of interest from endogenous choices in the data. Specifically, I estimate a dynamic model of investment in business groups with access to internal and external capital markets. Then, performing counterfactual experiments, I quantify the value of the internal capital markets for controlling and minority shareholders and evaluate which the main variables affecting it are.

In the model, a pyramidal business group formed by two firms, firm H and firm L, is completely controlled by a single shareholder, the controlling shareholder. However, the pyramidal ownership structure makes the controlling shareholder have higher cash flow rights in one firm (firm H) and lower cash flow rights in the other (firm L). The divergence between cash flow and control rights produces an agency problem between controlling and minority shareholders in firm L. Throughout this paper, I focus the analysis on pyramidal business groups because this structure generates a dramatic separation of control and cash flow rights. Moreover, it is one of the most common ownership structures across business groups around the world[1] (See Morck et al., 2005 and Masulis et al., 2011).

Since the maximization problem is solved by the controlling shareholders and not by minority shareholders, they can use the internal capital markets to reallocate resources between the two firms to benefit firm H, at the expense of minority shareholders in firm L. For instance, it could be optimal for the controlling shareholder to take resources away from one firm, even if leaving profitable projects unfunded, to finance projects in the other firm. Or it may be cheaper for the controlling shareholder to finance projects in one firm by raising external financing in the other, later reallocating the funds internally.

I assume internal capital reallocations are costly. As argued by Gopalan et al. (2014), the obscure nature of intra-group lending increases the opportunities for controlling shareholders to get private benefits and expropriate minority shareholders. For this reason, controlling shareholders may be forced to pay dissipative auditing costs to operate the internal capital market. Furthermore, controlling shareholders may be exposed to litigation risk, the possibility of being sued by minority shareholders if not acting in the best interest of all shareholders. Therefore, financing decisions in the model depend mainly on the relative costs of internal and external financing.

To confront the model with the data, I study a sample of Chilean business groups covering the years 1990–2015. The Chilean market, which is dominated by pyramidal business groups, provides a unique opportunity to study the internal capital markets of business groups, as the regulation requires firms to disclose all related party transactions, data not available in most markets. Using this dataset I estimate the model by simulated method of moments (SMM). This estimation procedure chooses the structural parameters of the model that make a set of simulated moments as close as possible to their sample

[1] Masulis et al. (2011) find that two-thirds of business groups in a broad sample of countries employ a pyramidal structure.

counterpart. I find that almost all the simulated moments used in the estimation match their empirical counterpart, which suggests that the model is a plausible approximation of what is observed in the data. Furthermore, the parameter estimates are all statistically significant, with the exception of the capital adjustment cost parameter.

Interestingly, I do not find a significant effect of the agency problem on investment or profitability. Group-affiliated firms' real decisions are almost unaffected by different ownership structures. However, the main effect of the ownership structure is on the allocation of external financing. Assuming both firms in the group face the same costs of external financing, from the controlling shareholder's point of view it is cheaper to raise external financing through the low cash flow rights firm, L, and reallocate these funds later through the internal capital markets. The model predicts, therefore, that most external financing will first flow to the lower cash flow rights firm.

The effect of diversification is somewhat similar. Real decisions are almost unaffected by the level of diversification. On the other hand, diversification has an important effect on financial decisions. As diversification increases, a coinsurance effect increases the opportunities to use the internal capital markets to finance firms internally and avoid the more expensive external capital markets.

To estimate the incremental value of the internal capital markets for minority shareholders, I perform counterfactual experiments in which I compare the value of equity of affiliated firms, which can access internal capital markets, with comparable non-group firms. If group-affiliated firms have higher equity value than non-group firms, I conclude that the coinsurance effect provided by the internal capital markets dominates agency problems effects, and value is created for minority shareholders. Alternatively, if non-group firms' value is higher, minority shareholders are expropriated, and value is destroyed. I find that shareholders in both firms in the group benefit from having access to an internal capital market. The values of firms H and L are on average 1.7% and 1.5%

higher than comparable non-group firms, respectively. Importantly, most of the value gain comes from substituting external with internal financing and not from a more efficient investment.

Finally, I study the sensitivity of the value of the internal capital markets to the ownership structure and diversification. I find that differences in the level of diversification are more important than differences in ownership structure in explaining the variation in the value added by the internal capital markets. One standard deviation change in the measure of diversification changes the value added by the capital markets by between 12% and 18%, while one standard deviation change in the percentage of ownership firm H has on firm L changes it only by about 7%.

This paper is related to the literature that studies the internal capital markets of business groups and specifically intra-group loans. For example, Gopalan et al. (2007) document that firms affiliated to Indian business groups use intra-group loans to transfer cash across group firms to support financially weaker firms and avoid default. Buchuk et al. (2014) find that Chilean firms that borrow internally invest and perform better than other firms, supporting the financing advantage view of business groups. On the other hand, Jiang et al. (2010) show evidence of controlling shareholders of Chinese groups using intra-group loans to expropriate minority shareholders.

Almeida et al. (2015) examine the effects of capital reallocations in Korean *chaebols* in the aftermath of the 1997 Asian financial crisis. Their findings suggest that internal capital markets of Korean groups helped them mitigate the negative effects of the Asian crisis on investment and performance. However, in their words, "*it is harder to provide evidence on the efficiency of capital allocation in a noncrisis period, as one lacks the salient financial shock that aids in identification*." This paper contributes by using a different identification method based on structural estimation, which considers the behavior of the representative firm for the average period.

The empirical method in this paper is similar to the one used to estimate other dynamic models of investment that study capital allocation, cash holdings and internal capital markets in U.S. conglomerates, such as Matvos and Seru (2014), Bakke and Gu (2017), Gu (2017). Besides focusing on a different corporate structure (business groups), this paper differs from them in that I use direct data on intra-group transactions to estimate the underlying parameters. This paper is also related to studies that use structural estimation to address agency conflicts. Lin et al. (2010) examine the impact of the divergence between insiders' control and cash flow rights on financial outcomes. The difference with this paper, however, is that their focus is on firm's external finance constraints rather than internal capital markets. Morellec et al. (2017) also estimate a dynamic model that incorporates agency conflicts between controlling and minority shareholders, but they do not incorporate internal capital markets. Their goal, instead, is on quantifying the agency conflicts.

The rest of the paper is organized as follows. Section 1.2 presents and analyzes the model. Section 1.3 describes the data. Section 1.4 discusses estimation and identification. Sections 1.5 and 1.6 present results and counterfactual exercises, and Section 1.7 concludes. The Appendix provides technical details.

1.2 Model

In this section, I present a dynamic investment model in discrete time for an infinitely lived business group with access to internal and external capital markets.

1.2.1 Ownership structure and production technology

A risk-neutral shareholder (the controlling shareholder or the controller) completely controls a pyramidal business group. The business group is composed of two firms,

$j = \{H, L\}$, one in which the controller has higher cash flow rights, H, and another in which the controller has lower cash flow rights, L. The ownership structure is as follows: the controller shareholder directly owns 100% of firm H's equity and 0% of firm L's equity. In addition, firm H owns a fraction γ of firm L's equity, which is sufficiently high for the controller shareholder to exert control over firm L. The ownership structure, which I assume is exogenous and constant through time,[2] creates a separation between the controller shareholder's control rights (100%) and cash flows rights (a fraction γ) on firm L's equity. Since we are interested in the controller's relative separation of control and cash flow rights, rather than the absolute ownership stakes, the assumed ownership structure is imposed without loss of generality. Figure 1.1 depicts the ownership structure.

Each firm in the group uses only its own capital stock, k_j, to produce per period profits $\pi(k_j, z_j)$, where z_j is a random productivity shock. I assume the profit function is $\pi(k_j, z_j) = z_j k_j^{\theta}$, with $0 < \theta < 1$. The curvature parameter, θ, captures decreasing returns of scale. The controller shareholder observes the random productivity shock for both firms in the group before making investment and financing decisions. I define $\boldsymbol{z}$ as the vector of the firm's shocks to productivity, which is assumed to follow the VAR(1) process in logs

$$\begin{aligned} \log(\boldsymbol{z}') &= \rho \log(\boldsymbol{z}) + \boldsymbol{\epsilon}', \;\; \boldsymbol{\epsilon} \sim N(0, \Sigma), \text{ where} \\ \Sigma &= \begin{pmatrix} \sigma^2 & \rho_{\epsilon}\sigma^2 \\ \rho_{\epsilon}\sigma^2 & \sigma^2 \end{pmatrix} \end{aligned} \tag{1.1}$$

in which a prime indicates a variable in the next period. $\boldsymbol{\epsilon}$ is a vector of innovations, which has a bivariate normal distribution with mean zero and variance matrix Σ. The matrix Σ has identical diagonal elements, σ; i.e., the volatility of the innovation to the

[2]For models with endogenous ownership structure see, for example, Almeida and Wolfenzon (2006); Aslan and Kumar (2012).

profitability shock is the same for both firms. ρ_ϵ is the correlation coefficient between the innovations of both firms, and ρ is the autocorrelation coefficient, which is also common for both firms. I define the Markov transition function associated to (1.1) as $g(\boldsymbol{z}'|\boldsymbol{z})$.

Firm j's capital investment at time t is denoted by I_j. Capital is purchased and sold at a price of one, and it depreciates at a rate of δ per period, with $0 < \delta < 1$. Therefore, the capital evolution over time is given by

$$k_j' \equiv (1-\delta)k_j + I_j. \tag{1.2}$$

Firms pay convex capital adjustment costs when they invest and disinvest, denoted by $\Phi(k, I)$. The functional form of these costs is given by

$$\Phi(k_j, I_j) = \frac{\phi}{2}\left(\frac{I_j}{k_j}\right)^2 k_j, \tag{1.3}$$

in which ϕ is a positive constant. This specification is common in the investment literature and follows Cooper and Haltiwanger (2006).

1.2.2 Financing

Firms can finance their capital investment with current profits, intra-group debt, external financing or a combination of them. Each period, firms in the business group have a stock of intra-group debt equal to d. I define d to be positive when firm H owes firm L and negative otherwise. Since I do not focus on the pricing of intra-group debt, but rather in the capital allocation aspect of the internal capital market, I make the simplifying assumption that intra-group debt pays the exogenously given discount interest rate, r, per period.[3] Considering that the model is estimated with a sample of Chilean business groups, and the Chilean regulation requires related party transactions to be made at market rates, using the discount rate as the interest rate for intra-group loans seems a reasonable assumption.

Because I am interested in the internal flow of funds rather than the composition of external financing, I follow Nikolov and Whited (2014) and do not distinguish between debt and equity financing.[4] Hence, the cash distributions/issuance to shareholders, denoted by e, correspond to the difference between sources and uses of funds of each firm

$$e_H = \pi_H(\cdot) - I_H - \Phi_H(\cdot) - d' + (1+r)d \tag{1.4}$$

$$e_L = \pi_L(\cdot) - I_L - \Phi_L(\cdot) + d' - (1+r)d, \tag{1.5}$$

When e_j is positive, the firm is distributing cash to its shareholders; when e_j is negative, the firm is raising outside financing. In equation (1.4) I have assumed that firm L's cash distributions/issuance go directly to the controller shareholder and do not enter in firm H's equation; i.e., firm H cannot use firm L's dividends as cash to purchase capital nor use its own cash to directly finance firm L's investments. The only flow of cash between the two firms is through intra-group lending. Therefore, while the term $(\gamma \times e_L)$, the fraction of firm L's dividends owned by firm H, will appear later on the controller shareholder's utility function, it is not considered in the expression for e_H in equation (1.4). This assumption is meant to isolate intra-group lending as the only channel of internal capital

[3]A model in which the controller can choose this rate is out of the scope of this study, and empirically testing it would require data on intra-group loans prices, which is not available in most cases.

[4]If I were to assume separate equity and debt external financing, the model would require two extra state variables with the stock of external debt of each firm, which would turn the state space of the model too large, making it unfeasible to estimate.

markets to the group.[5] It also seems adequate given that in the model, e_j is representing an aggregate of many forms of external financing, including external debt and equity financing.

I assume that for each dollar of external financing raised, the firm must pay a linear cost equal to

$$\Lambda(e_j) = \mathbb{I}_{\{e_j<0\}}\lambda e_j, \tag{1.6}$$

where $\mathbb{I}_{\{e_j<0\}}$ is an indicator function that equals one when the firm raises funds. This specification, that follows Nikolov and Whited (2014), is motivated by flotation costs of debt and equity financing.

Finally, operating the internal capital markets is assumed to be costly for two reasons. First, as Gopalan et al. (2014) note, intra-group transfers present the opportunity for the insider to expropriate outside investors. To prevent this behavior, external investors may require auditing the internal capital market activities. Furthermore, the controller may want to improve his reputation by disclosing information about internal transfers. I assume that this auditing imposes a cost to the insider. Second, since internal transfers may be motivated to benefit one firm in the group at the expense of the other, the insider may fear minority shareholders taking legal actions. Therefore, this cost may also be justified by assuming the controller bears litigation risk costs when reallocating resources among firms in the group. Because both of these arguments are more likely to emerge when the transfers are relatively large, I assume the cost of operating the internal capital market, $\Psi(\cdot)$, is convex and takes the following form

[5]See Gopalan et al. (2014) for a model in which a firm's dividend policy is used as a channel of internal capital markets in business groups.

$$\Psi(k_H, k_L, d) = \frac{\psi}{2}\left(\frac{d^2}{k_H + k_L}\right), \tag{1.7}$$

where ψ is a positive parameter. The cost is proportional to the squared intra-group debt balance, and it is scaled by $k_H + k_L$, the total of assets under control.

1.2.3 The objective function

The controller shareholder's problem is to choose capital investment in each company in the group and the stock of intra-group debt between them, $\left\{k'_H, k'_L, d'\right\}$, every period to maximize the value of discounted expected payoffs, discounting at the opportunity costs of funds, r. The Bellman equation of the problem is

$$\begin{aligned} V(k_H, k_L, d, \boldsymbol{z}) \;=\; & \max_{\left\{k'_H, k'_L, d'\right\}} \Bigg\{ e_H + \Lambda(e_H) + \gamma\left(e_L + \Lambda(e_L)\right) - \Psi(k_H, k_L, d) \\ & + \frac{1}{1+r} \int V(k'_H, k'_L, d', \boldsymbol{z}') dg(\boldsymbol{z}'|\boldsymbol{z}) \Bigg\}, \end{aligned} \tag{1.8}$$

where $V(\cdot)$ corresponds to the value of firm H conditional on the state variables $\left\{k_H, k_L, d, \boldsymbol{z}\right\}$, and $dg(\boldsymbol{z}'|\boldsymbol{z})$ is the transition density of the profitability shocks. The first two terms on the right hand side of equation (1.8) are the cash distributions/issuances and issuance costs from firm H. The third term represents the fraction γ of the corresponding cash flows coming from firm L. The fourth term is the auditing cost. The last term represents the discounted expected value of firm H in the next period.

1.2.4 Optimal policy functions

In this section, I examine the optimal intra-group lending policy function. The optimal policy function is the rule that specifies for each set of states $\{k_H, k_L, d, \boldsymbol{z}\}$ the optimal choice of decision variables $\left\{k'_H, k'_L, d'\right\}$ for the next period. To simplify the analysis, I assume in this section that V is once differentiable, although, as noted in Riddick and Whited (2009), this is not a necessary condition for the existence of a solution to the problem in equation 1.8. The first order condition of the maximization problem with respect to d' is

$$\left(1+\mathbb{I}_{\{e_H<0\}}\lambda\right)-\gamma\left(1+\mathbb{I}_{\{e_L<0\}}\lambda\right)=\frac{1}{1+r}\int\frac{\partial V(k'_H,k'_L,d',z'_j)}{\partial d'}dg(z'_j|z'_j). \tag{1.9}$$

The left-hand side of this equation represents the net marginal cost of intra-group financing. The first term corresponds to the marginal cost of increasing intra-group financing. When firm H is raising external financing, this is the marginal cost of incrementing external financing. When firm H is not raising external financing, this is the marginal cost of cutting firm H's dividends. The second term corresponds to the fraction γ of the marginal benefit of increasing intra-group financing. If firm L is raising external financing, this is the marginal benefit of reducing external financing. If firm L is making distributions, the marginal benefit is the increment in distributions made by firm L. Using the envelop condition we can express equation 1.9 as

$$(1+r)=\frac{\int\left\{(1+r)\Big(\left(1+\mathbb{I}_{\{e'_H<0\}}\lambda\right)-\gamma\left(1+\mathbb{I}_{\{e'_L<0\}}\lambda\right)\Big)-\frac{\psi\, d'}{(K_H+k_L)}\right\}dg(z'_j|z'_j)}{\left(1+\mathbb{I}_{\{e_H<0\}}\lambda\right)-\gamma\left(1+\mathbb{I}_{\{e_L<0\}}\lambda\right)} \tag{1.10}$$

This equation shows how the optimal d' is such that the rate of substitution between the marginal cost of intra-group financing today and the expected marginal cost of intra-group financing next period equals the discount rate $(1+r)$.

1.2.5 Numerical policy functions

In this section, I explore optimal policy functions by numerically solving the dynamic model presented in Section 1.2 via value function iteration. Details of the numerical solution are described in the Appendix. Figure 1.2 shows optimal responses of investment, intra-group debt, and distribution/external financing to the productivity shocks, z_j. The left and right columns of panels show responses to firm H's and L's shocks, respectively. Investment is defined as I_j/k_j, intra-group debt as $-d/k_H$ for firm H and d/k_L for firm L, and distributions/external financing as e_j/k_j. The model is parameterized at the estimated parameters in Panel B of Table 1.2, holding the current stock of capital at its simulated average, the current stock of intra-group debt at zero, the other firm's productivity shock at zero, and letting the own productivity shock take values in the interval $[-2\sigma/\sqrt{1-\rho^2}, 2\sigma/\sqrt{1-\rho^2}]$.

Both firms' investment responses to their own and the related firm's productivity shock are similar. Optimal investment steeply responds to high realizations of the own productivity shock, whereas they engage in limited disinvestment for negative realizations. On the other hand, the optimal investment response is practically flat against shocks to the other firm's productivity.

Unlike investment policies, financial policies are different between the two firms. Considering first the responses to firm H's shocks on the left column, given positive realizations of its own productivity shock, firm H gets a large amount of internal debt and does not raise external financing. The funds lent by firm L come from firm L's internal profits and external financing. For low realizations of its own shock, firm H lends to firm

L a fraction of its generated cash, which is paid by firm L as dividends. The convex form of the auditing cost and the absence of cash saving in the model explain this behavior. To avoid incurring higher convex auditing costs and expensive external financing costs in the future, firm H lends to L as a way of saving to fund future investment.

Responses to firm L's shock to productivity on the right column show that for positive realizations, firm L receives a lower fraction of financing through internal debt compared to the case of firm H discussed above, and the rest is funded by raising external financing. For low realizations of the productivity shock, there is no internal financing; therefore, firm L pays all its generated cash as dividends.

The differences between the two firms' financial policies show the effect of the separation between control and cash flow rights. To finance investment in firm H, it is cheaper to raise external financing in firm L and then transfer it to firm H through the internal capital market. This is because the controller pays only a fraction γ of the external financing costs. To finance investment in firm L, on the other hand, the internal transfer is limited to the cash generated by firm H, without relying on costly external financing.

1.3 Data

In order to estimate the model, I collect data on Chilean business groups from 1990 to 2015. Accounting data comes from *Superintendencia de Valores y Seguros* (hereafter, SVS), the Chilean stock market regulator. In most countries, direct data on the internal capital markets of business groups is not easily available. The Chilean market offers an attractive source of data in this regard. As a consequence of a debt crisis that hit the country in 1981, the government implemented a strict approach toward business groups (Khanna and Rivkin, 2006). Since 1988, the SVS tracks the composition of major business groups in the country, ownership links are publicly disclosed, and related party transactions are recorded in the financial statements of every company. The law also requires related party loans to be made at the prevailing market interest rate. A legal prohibition on cross-holdings, which simplifies significantly the configuration of Chilean control pyramids, was also introduced in the aftermath of the crisis.

Every publicly traded firm reports a line called *notes and accounts payable to related companies* on the liability side of the balance sheet, which comes separated by the maturity of the transaction (short-term or long-term). A similar line on the asset side contains *notes and accounts receivable from related companies*. I define the variable *internal financing* for a given firm as the difference between these two lines in the balance sheet. I focus on non-consolidated financial statements since any transaction between related parties disappears whenever a firm consolidates its statements with another company (as the transaction is both on the asset side and the liability side of the consolidated entity). The ownership links among group-affiliated firms and the stakes owned by ultimate controlling shareholders were collected from the annual reports.[6] Using this information, I define a business group as two or more publicly traded firms controlled by the same shareholder or family.

I exclude from my sample all financial firms such as banks, insurance companies, or private pension funds. I also drop firms for which the time series average of capital stock over book value of total assets is less than 15%. This is to ensure that all firms in the sample are productive firms, and other firms, such as holding companies, are excluded. The sample selection results in a panel of 33 business groups, 78 firms, and 1,613 firm-year observations.

Table 1.1 reports summary statistics for firms in the sample. The first four variables are used in the estimation, and they are scaled by the stock of capital. I scale these

[6] I thank Francisco Urzúa for providing these data.

variables by the stock of capital, defined as property, plants, and equipment, instead of the book value of total assets, for two reasons. First, variables in the model are scaled by the stock of capital, so it makes sense to define them in the same way in the data. Second, when scaling by the stock of capital, ratios look closer to those found for U.S. firms. The mean of internal financing is -1.9%, and the median is practically zero. One would expect this value to be close to zero, as the sample mean aggregates firms on the lending and borrowing side of the relation, which cancel out. However, the standard deviation is 26%, which suggests that the internal capital markets of the business groups in the sample are quite active. The mean external financing flow is 1.6%, the average cash flow is 15.5% and firms invest 8.8% on average.

Not all business groups in the sample have the two-firm pyramidal structure presented in the model; however, most of them can be viewed as one or more *two-firm branches*. Then, to relate the data with the ownership structure in the model, I classify firms as being of type H or L. I define firms type H as those for which the cash flow rights of the controller are greater than the average cash flow rights of the controller on all the firms in the group. Firms are classified as type L otherwise. Using this definition, the average controller's cash flow rights on firm H are 58.9% and on firm L are 39.5%. Therefore, in the estimation I set the parameter γ, the ownership firm H has on firm L, equal to 67% $(= 0.395/0.589)$.

I define the cash flow correlation as the mean correlation of the residuals from a first-order auto-regression of cash flows between each pair of firms in the same business group. The mean cash flow correlation is somewhat low, equal to 0.13.[7] This suggests that firms in the sample of business groups, which have access to internal capital markets, benefit from their relatively high level of diversification.

[7] As a comparison, Bakke and Gu (2017) estimate the correlation between the profit shocks for divisions of U.S. conglomerates as 0.205.

1.4 Estimation and Identification

In this section, I describe the estimation methodology, identification strategy, and estimation results.

1.4.1 Parameters and selection of moments

I estimate most of the parameters using the simulated method of moments (SMM). The interest rate, the mean ownership link between the firms in the group and the cross-sectional correlation of the profitability shock's innovation, however, are estimated separately. I set the interest rate parameter at 3.3%, which is the average three-month real interest rate over the sample period for deposits in the Chilean financial system. As explained in Section 1.3, I set the ownership stake parameter, γ, equal to 0.67 and the correlation between each firm's innovation to profitability equal to 0.13.

I define Θ as the vector containing the seven parameters to be estimated using SMM: the curvature of the profit function, θ, the convex cost of capital adjustment, ϕ, the linear cost of external financing, λ, the autocorrelation of the shock to profitability and standard deviation of its innovations, ρ and σ, the depreciation rate δ, and the quadratic auditing cost parameter, ψ. The SMM estimation chooses the parameters Θ that minimize some *distance* from a set of simulated moments to the actual data moments. Details of the estimation are described in the Appendix. The set of moments I match includes moments related to the real decisions of the business group and moments related to its financial policy. For the purpose of the parameter estimation, I estimate data moments as well as simulated moments pooling all firms in the sample, without distinguishing whether they are firms H or L. Later, I examine differences between firm H's and firm L's simulated policies.

On the real decisions side, first I match the mean rate of investment, which in the model corresponds to I/k. This moment helps identify the rate of depreciation δ. Next, I match the mean of the ratio of profits to capital, zk^{θ}/k. This moment helps identify the parameter θ. I also match the autocorrelation of profits and the variance of its innovation, which are the slope coefficient and error variance from a first-order autoregression of the ratio of profits to capital. These moments identify the autocorrelation and standard deviation of the innovation parameters, ρ, and σ.

The next moments are related to the business group's financial policy. First, I match the frequency of internal financing, which I define as the fraction of periods in which one of the firms in the group is a receiver of funds. Following Buchuk et al. (2014), I define a receiver firm as one for which its stock of intra-group debt is greater or equal to 5% of its stock of capital. This moment helps identify parameters related to real decisions since they determine the frequency of funding requirements. Also, this moment is informative about the maturity of internal loans. The longer the maturity of a loan, the higher the number of periods a firm stays as a receiver of funds, which increases the estimated frequency of internal financing. I also match the second moment of the stock of intra-group debt, b/k. This moment helps identify primarily the convex auditing cost parameter, ψ. I do not match the first moment of this variable, as it takes positive and negative values that cancel out in the time series, making its serial mean close to zero. The second moment is, therefore, more informative about the level of internal capital market activity. Finally, I match the first and second moments of external financing, e/k. These moments help identify the linear cost of external financing, λ, and capture the business group's external financial policy.

1.4.2 Estimation results

Table 1.2 presents the results of the SMM estimation. Panel A shows actual and simulated moments from the model, as well as t-statistics for their difference. Panel B shows parameter estimates and standard errors. The model simulated moments statistically match most of the actual moments in Panel A. Specifically, the model is able to match the moments that capture the real decisions and, importantly, the internal capital market variables. The estimation procedure struggles to match the first moment of the external financing flow, which is overestimated by the model. However, the hypothesis that the model matches all eight moments is not rejected (the p-value of the J-test is 0.8726). It is important to note that the number of observations in this study is relatively low, and the model could surely be rejected with enough additional data (see Taylor (2013) for this argument).

Most of the estimated parameters are significantly different from zero. The estimated curvature of the profit function parameter, θ, is somewhat lower than what the literature finds for U.S. firms (see DeAngelo et al. (2011) and Nikolov and Whited (2014) for stand-alone firms, and Bakke and Gu (2017) for conglomerates). The volatility of the innovation to the profitability shock, σ, is much higher than what other studies find for typical U.S. firms. This suggests that firms in emerging markets face higher uncertainty than firms operating in developed countries. The autocorrelation parameter, ρ, is between the typical values found for U.S. firms. The capital adjustment cost parameter is very small and not statistically different from zero. The estimated depreciation rate of capital is 3.73%.

The parameter ψ, which captures the costs involved in operating the internal capital markets, is statistically significant. At the average simulated stock of internal debt, the point estimate of this parameter translates in auditing costs of 0.48% of the size of the loan. Finally, according to the estimated cost of the external financing parameter, λ, firms pay 6.37% in flotation costs when they raise funds from external capital markets.

With the estimated parameters in hand, I return now to the issue of parameter identification. Table 1.3 shows the standardized sensitivity of parameter estimates to estimation moments of Andrews et al. (2017). This is a local measure of how sensitive a parameter is to a given moment, and considers information on both how sharply a simulated moment responds to a given parameter and how accurately an empirical moment is estimated. The standardized version of this metric lies between -1 and 1, with the most sensitive relations between parameter and moments having larger magnitudes in absolute value. Each row in the table corresponds to a moment used in the estimation, and each column to a parameter. To reduce clutter, the table shows only numbers greater than 0.2 in absolute value.

The computed sensitivities are consistent with the intuition discussed in Section 1.4.1. For instance, the depreciation rate parameter, δ, is most sensitive to the average investment rate, and the standard deviation of the innovation to the profitability process, σ, is most sensitive to the autocorrelation of profits and mechanically to the variance of the innovation of profits. The external financing cost parameter, λ, is strongly sensitive to the average of external financing flow. It is interesting to note that the frequency of internal financing is stronger in identifying parameters associated with real variables than financial variables. The sensitivity of the curvature of the profit function, θ, the adjustment cost parameter, ϕ, and the depreciation rate, δ, to the frequency of internal financing are 0.69, 0.795, and 0.512, respectively, while the sensitivity of the auditing cost, ψ, which relates to the cost of operating the internal capital markets, to this moment does not exceed the threshold of 0.2. The variance of external financing only exceeds the threshold for the auditing cost, ψ; however, since this is a local sensitivity measure, this moment may still be informative for other ranges of parameters.

1.5 Investment and Financial Effects

In this section, I explore the effect of the ownership structure and diversification on the investment and financing behavior of business groups.

1.5.1 Ownership structure

In the model presented in Section 1.2, the ownership structure is captured by the parameter γ, which represents the equity stake firm H owns on firm L, or equivalently, one minus the wedge between the controller cash flow and control rights. Table 1.4 shows different model simulated moments as a function of the ownership link parameter, γ. Each pair of columns reports moments for firm H and L separately, except for γ equal to one, in which, from the controller's point of view, both firms are identical.

Results in Table 1.4 indicate that financial moments, more than real moments, are sensitive to the parameter γ. The main takeaway here is that the agency problem generates misallocation of external financing. As the agency problem increases (γ decreases), external financing flow in firm H decreases and gets substituted by higher external financing flow in firm L. This is because the controller pays only a fraction γ of financing costs in firm L, making it sometimes cheaper to finance investment in firm H by raising external financing from firm L, and then transferring funds internally. Contrary to what one would expect, however, also when γ decreases, the frequency of internal financing decreases for firm H and increases for firm L. As explained in Section 1.2.5, in some cases firm H lends to firm L as a way of saving for future periods, which explains this pattern.

An alternative way of looking at the financial misallocation is by computing correlations between internal financing and investment. Higher correlation is associated with firms using internal debt efficiently to finance investment. Table 1.4 shows that this correlation is sensitive to the parameter γ. As γ decreases, the correlation between internal financing and investment increases for firm H and decreases for firm L. This is consistent with the idea that as the agency problem increases, firm L raises external funds, not to finance its own projects but projects in firm H.

Real moments, on the other hand, are almost unresponsive to the parameter γ. For instance, investment is only slightly affected by γ. For a value of γ equal to 0.3, average investment rates are 8.8% and 7.8% in firms H and L, respectively, which is not very different from the 8.6% for the case with γ equal to one. Operating profits are even less sensitive to the parameter γ. Average, standard deviation, and serial correlation of profits are practically constant for all values of γ. Since in the model I do not explicitly incorporate private benefits of control, and investment is barely affected by the agency problem, most of the benefits the controller can exploit through internal reallocations come from reducing the total cost of external financing.

1.5.2 Diversification

Diversification is captured in the model by the correlation of shocks to profitability between the two firms in the group, ρ_ϵ. As this parameter decreases, the business group is more diversified. Table 1.5 shows different model-simulated moments as a function of this correlation parameter. As in the previous section, each pair of columns reports moments for firm H and L separately.

Similar to the case of ownership structure, financial moments, more than real moments, are sensitive to the parameter ρ_ϵ. As one would expect, when diversification increases (ρ_ϵ decreases), the frequency of internal financing increases for both firms, as there is greater scope for coinsurance among group firms. Similar to the case of ownership structure as well, firm L gets internal financing more frequently than firm H. The same explanation for this given in the previous section applies here. Next, the standard deviation of internal financing, which is related to the magnitude of intra-group loans, also increases with diversification, more than doubling when ρ_ϵ goes from 0.8 to -0.8. Correlation between internal financing and investment is strongly sensitive to the parameter ρ_ϵ. As diversification increases, the correlation between internal financing and investment increases for firms H and L. Note that for very low diversification ($\rho_\epsilon = 0.8$), the internal financing-investment correlation for firm H is much higher than for firm L, suggesting that for this case, internal transfers are made mainly with the objective of benefiting firm H, instead of mutual coinsurance.

External financing is also sensitive to the parameter ρ_ϵ. As ρ_ϵ decreases, the coinsurance effect allows the use of internal capital markets to substitute costly external financing. When ρ_ϵ goes from 0.8 to -0.8, average external financing flow decreases to less than one fourth in both firms.

Real moments, on the other hand, are almost unaffected by the parameter ρ_ϵ. For instance, for a value of ρ_ϵ equal to -0.8, average investment rates are 9.3% and 9.0% for firms H and L, respectively, which are only 1.3% higher than the case with ρ_ϵ equal to 0.8. Here again, operating profits are even less responsive to the parameter ρ_ϵ than investment. Mean, standard deviation, and serial correlation of profits are practically constant for all the different values of ρ_ϵ.

These results complement the literature on the effect of diversification on business groups' policies. For instance, Khanna and Yafeh (2005) find that group affiliation is correlated with smooth operating profitability, suggesting that coinsurance among group-affiliated firms is an important function of diversified business groups. Their estimate of a 20–30% reduction in the standard deviation of operating profitability for group firms compared to non-affiliated firms, however, is somewhat larger than the 0.3–5.1%[8] predicted by this model. Jia et al. (2013) show direct evidence of the use of intra-group

[8]Numbers not reported in Table 1.5.

transactions in diversified Chinese business groups, consistent with the coinsurance predictions in this paper.

Overall, the comparative statics presented in this section suggest that financial policies of business groups, and not investment policies, are more sensitive to the ownership structure and the level of diversification.

1.6 Value Effects

In this section, I quantify the incremental value of the internal capital markets of the group by comparing a business group in which its member firms can access external capital markets and can lend to each other and a business group in which firms can only get external financing. Besides estimating the value created for the controlling shareholder, in this experiment I assess whether minority shareholders in firm L are better or worse off when the group can operate an internal capital market. To do this, I calculate the value of minority shares on each firm recursively, using the following equation

$$V_j(k_H, k_L, b, \mathbf{z}) = \max^*_{\{k'_H, k'_L, b'\}} \left\{ e_j + \Lambda(e_j) + \frac{1}{1+r} \int V_j(k'_H, k'_L, b', \mathbf{z}') dg(\mathbf{z}, \mathbf{z}') \right\}, \quad (1.11)$$

where max* denotes optimal policies for the controller, and V_j is the value of firm j.

1.6.1 Value effect of the ownership structure

Panel A in Table 1.6 presents the results of the experiment for different values of the equity percentage firm L owns on firm H, γ, between 0.3 and 1. I measure the value gain as the percentage increase in the time series average value of the firm, V_j. For γ equal to one, both firms in the group have the same value gain of roughly 1.6%. As one would expect, when the agency problem becomes more severe (γ decreases), the value gain increases for firm H and decreases for firm L. With the estimated parameters, firm L is always better off by having access to internal capital markets than not. However, this does not rule out the possibility that for another set of parameters, there is some level of agency problem (measured by γ) at which the expropriation effect dominates the coinsurance effect brought by the internal capital market, and minority shareholders in firm L are worse off (see the case of no diversification below).

As mentioned above, under the model assumptions, all value gains come from firms being able to substitute external financing with internal financing. Hence, Table 1.6 shows also the reduction in external financing due to access to internal capital markets. When γ is one, firms with access to internal capital markets have a 2.9% less average flow of external financing as a fraction of assets compared to an equivalent firm without access to internal capital markets. As γ decreases, firm H's reduction in external financing increases, while firm L's approximates zero.

1.6.2 Value effect of diversification

Panel B in Table 1.6 presents the results of the experiment for different values of the diversification parameter, ρ_ϵ, between -0.8 and 1. In the case of no diversification ($\rho_\epsilon = 1$), the time series average of firm H's value is 0.91% higher than the value of a comparable non-group firm. Firm L's value is even slightly reduced by 0.04% when compared to a non-group firm. As diversification increases, both firms in the group are better off, with the firm H always getting a higher fraction of the benefit from diversification than firm L.

Again, the value gain from diversification comes from a coinsurance effect, which reduces the need for costly external financing. As reported in the bottom rows of Panel B, the internal capital markets allow firm H to reduce its external financing by between 1.38% and 3.76%. Firm L, on the other hand, may even increase its access to external financing for low diversification levels in order to benefit the controller shareholder. For high diversification levels, firm L reduces external financing by up to 3.38%.

To put these numbers in perspective, here I compare with the literature. In contrast to the findings in this paper for Chilean business groups, Claessens et al. (2002) find that for a sample of eight East Asian economies, the concentration of control is negatively correlated with firm value. They find that one standard deviation increase in the separation of control and cash flow rights lowers values by more than 5.3%. However, using the Asian financial crisis of 1997 as an exogenous shock, Lemmon and Lins (2003), Baek et al. (2004) and Almeida et al. (2015) also study the effect of group affiliation and control concentration on firm value for East Asian firms reaching different conclusions. Overall, they find that the drop in firm value during the crisis period is about 6–14% larger for non-group firms than for group-affiliated firms. However, for the group of affiliated firms in which the controller's separation between control and cash flow ownership is high, the drop in firm value is about 12% larger than other affiliated firms. These numbers are consistent with the predictions in the model described in Section 1.2, but the effects seem larger in magnitude. However, besides being a different sample, the counterfactual experiment in this paper compares affiliated and non-affiliated firms in the steady state, as opposed to a crisis period, which can explain these differences.

Along with estimating the level of the value added by the internal capital markets, it is also interesting to assess the relative importance of the variables affecting it. I measure these effects by estimating the percentage change in the value added by the internal capital market caused by a change in a variable by two standard deviations.[9] For instance, the standard deviation of the ownership structure parameter, γ, in the data is 0.19. I compute the percentage change in the value of the internal capital market for firm H

[9] Note that the small sample size makes unfeasible to estimate the parameters of the model by splitting the sample for different values of γ and ρ_ϵ.

from increasing the parameter γ from 0.48 to 0.86 (a standard deviation above and below 0.67), which is a negative 7%.

Panel C in Table 1.6 presents sensitivities to the ownership structure parameter, γ, and to the diversification parameter, ρ_{ϵ}. The value of the internal capital market for firm H is more sensitive to diversification than to the ownership structure, negative 11.95% and negative 7%, respectively. On the other hand, the sensitivity of value for firm L is much stronger to diversification than to the ownership structure, negative 18.41% versus 7.42%. These results suggest that, at least for this sample, diversification of the business group is more important than its ownership structure in explaining differences in the value added by the internal capital markets.

1.7 Concluding remarks

In this paper, I estimate a structural model of investment in business groups, in which firms can lend and borrow internally. I find that the value of internal capital markets is positive for controlling shareholder and minority shareholders. This finding does not support the hypothesis that on average minority investors are expropriated by controlling shareholders. I interpret this result as evidence that the coinsurance effect provided by the capital markets outweighs agency problems generated by the ownership structure.

Comparative statics exercises suggest that the ownership structure and diversification affect financial policies more than investment policies of business groups. A novel prediction from these exercises is that the ownership structure may generate a type of misallocation of external financing. Here, the controller has incentives to use the internal capital markets of the group to depart from what would be the optimal financial policy in the absence of agency problems, reducing the equity value for minority shareholders. To the best of my knowledge, no previous study has explored this predicted misallocation of external financing.

The sensitivity exercises show that what better explains differences in the value created by the internal capital markets is differences in risk sharing across affiliated firms related to different levels of diversification, rather than differences in expropriation risk related to different ownership structures.

Finally, it is important to mention that one limitation of this study is that I do not explicitly incorporate in the model a direct form of expropriation of minority shareholders. The agency problem in the model represents, therefore, a lower bound to the potential for expropriation in business groups.

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Appendix

Appendix 1.A Model solution

To solve the model numerically, I start by discretizing the state space $\{k_H, k_L, b, z_H, z_L,\}$. To discretize the two correlated processes $\log(z_H)$ and $\log(z_L)$, first I transform the bivariate process in (1.1) into two independent $AR(1)$ processes. Then, I approximate each independent process into a discrete-state Markov chain using the method in Tauchen (1986) with 7 evenly spaced grid points on the interval $[-2\sigma/\sqrt{1-\rho^2}, 2\sigma/\sqrt{1-\rho^2}]$. Finally, I inverse transform the two independent grids into one grid with 49 points corresponding to the correlated process.

The grid for the capital stock has 62 points with geometrically increasing intervals at a rate of δ. This grid is centered at the steady state value of capital for a single firm. Finally, the grid for the intra-group stock of debt has 15 equally spaced points in the interval $[-3k^{ss}/2, 3k^{ss}/2]$, where k^{ss} denotes the steady-state level of capital, and the limits of the intra-group debt grid are arbitrarily chosen so that its simulated value lies always between them. I let the choice of intra-group debt take 5 equally spaced points between the grid points, for which I linearly interpolate the value function.

I find the solution to the Bellman equation in (1.8) by iteration of the value function, which gives a value function $V(k_H, k_L, d, \boldsymbol{z})$ and the optimal policy function $\left\{k'_H, k'_L, d'\right\}$. I find firm H's and firm L's equity values by iterating the value function in equation (1.11) using the optimal policy function corresponding to (1.8).

Appendix 1.B Estimation

The SMM estimator of the parameter vector Θ is

$$\hat{\Theta} = \arg\min_{\Theta} g_n(\Theta)' \widehat{W} g_n(\Theta),$$

with

$$g_n(\Theta) = \left[\widehat{M}(x) - \frac{1}{S}\sum_{s=1}^{S}\widehat{m}\left(y_s, \Theta\right)\right],$$

where $\widehat{M}(x)$ is a vector of moments estimated using the data, x, $\hat{m}$ is the sth vector of corresponding moments using the simulated data, y_s, S is the number of simulations, and $\widehat{W}$ is a positive definite matrix that converges in probability to a deterministic positive definite weighting matrix. To remove heteregeneity in the panel data, all means are computed using raw data, all variances are computed using demeaned data within the firm level, and autocorrelations are computed following the double differences approach in Han and Phillips (2009). We use the optimal weighting matrix $\widehat{W} = \left[n\,\mathrm{var}(\widehat{M}(x))\right]^{-1}$. We calculate the covariance matrix of empirical moments, $\mathrm{var}(\widehat{M}(x))$, by covarying their influence functions, $\psi_{\widehat{M}(x)}$.

The estimated simulated moments, $\hat{m}(y_s, \Theta)$, are estimated from simulated samples of length n, which are generated using the optimal policy functions from the problem (1.8). To remove the effect of initial values, I simulate the model for 100 periods and drop the first 60.

Applying the result of Pakes and Pollard (1989) with the optimal weighting matrix, we get

$$\sqrt{n}\left(\widehat{\Theta} - \Theta\right) \quad \xrightarrow{d} \quad \mathcal{N}\left(0, \mathrm{avar}(\widehat{\Theta})\right),$$

in which

$$\mathrm{avar}(\widehat{\Theta}) \quad = \quad \left(1 + \frac{1}{S}\right)\left(\Gamma'\widehat{W}\Gamma\right)^{-1},$$

where $\Gamma = \operatorname*{plim}_{n\to\infty} \partial\,\hat{g}_n(\Theta)/\partial\Theta'$, which I numerically estimate differentiating $\hat{g}_n(\hat{\Theta})$ with respect to Θ.

Finally, the test of the model's overidentifying restrictions is

$$\left(\frac{nS}{1+S}\right)\left(g_n(\Theta)'\,\widehat{W}g_n(\Theta)\right) \xrightarrow{d} \chi^2_{p-q}$$

where p is the number of moments, and q is the number of parameters.

Figure 1.1: Business group structure

This picture depicts the ownership structure of the business group assumed in the model. There are two firms, H and L, in which the insider (or controller) has high and low cash flow rights, respectively. α represents the fraction of the equity in firm H owned by the insider. γ represents the fraction of the equity in firm L owned by firm H.

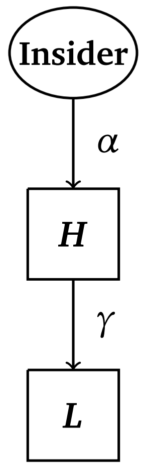

Figure 1.2: Policy functions

This picture compares firm H and L's optimal investment and financial policies as a function of the log of firm H's (left column) and firm L's (right column) productivity shocks z_H and z_L. All values are normalized by firm H's capital.

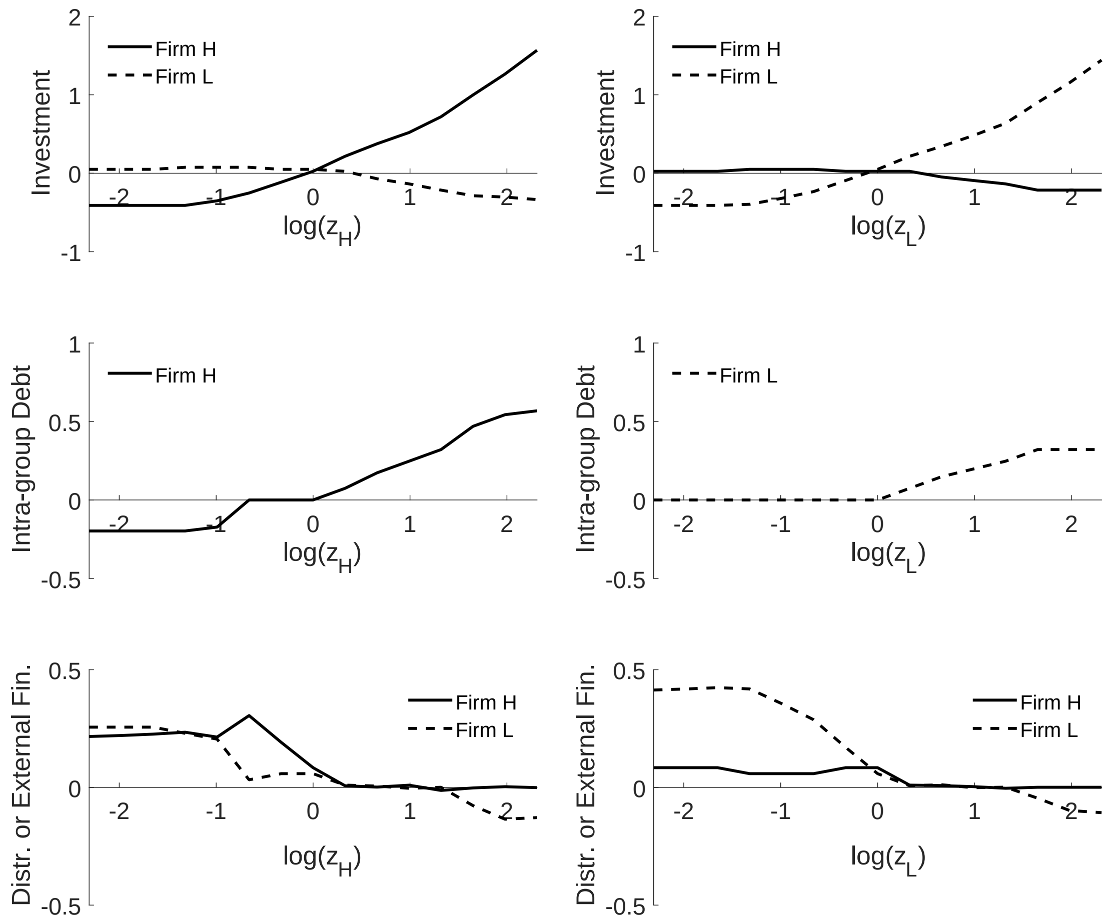

Table 1.1: Summary statistics

This table reports summary statistics for firm characteristics. The sample covers non-financial Chilean group-affiliated firms from 1990 to 2015. The sample includes 1,613 firm-year observations, 78 firms, and 33 business groups.

	Mean	SD	25%	50%	75%
Internal financing	−0.019	0.264	−0.066	0.000	0.035
External financing flow	0.016	0.121	−0.035	0.000	0.027
Cash flows	0.152	0.228	0.066	0.146	0.251
Investment	0.088	0.138	0.021	0.077	0.147
PPE / Assets	0.516	0.247	0.345	0.522	0.711
Leverage	0.147	0.141	0.003	0.117	0.250
Total Assets ($B)	0.340	0.452	0.043	0.147	0.415
Cash flow rights Firm H	0.589	0.223	0.445	0.585	0.700
Cash flow rights Firm L	0.395	0.184	0.270	0.385	0.467
Cash flow correlation	0.134	0.161	−0.020	0.133	0.193

Table 1.2: Estimation results

This table presents estimation results of the model presented in Section 1.2 using the simulated method of moments procedure (SMM). Panel A shows actual and simulated moments and the t-test statistic for the individual moment conditions. Panel B reports parameter estimates and standard errors in parenthesis. θ is the curvature parameter of the profit function. ρ is the serial autocorrelation of the log of profit shocks, and σ is the standard deviation of their innovations. ϕ is the convex capital adjustment cost, δ is the depreciation rate, ψ is the auditing cost parameter, and λ is the linear cost of external financing.

A. Moments

	Actual moments	Simulated moments	t-test
Average investment (I/k)	0.0864	0.0935	−1.7628
Average profits (zk^{θ}/k)	0.1469	0.1351	1.6682
Autocorrelation of profits (zk^{θ}/k)	0.7617	0.7625	−0.0648
Variance of the innovation to profits (zk^{θ}/k)	0.0136	0.0137	−0.1810
Frequency of internal financing (b/k)	0.3597	0.3582	0.1059
Variance internal financing (b/k)	0.0476	0.0442	1.0423
Average external financing (e/k)	0.0197	0.0350	−4.5901
Variance external financing (e/k)	0.0134	0.0142	−1.1265

B. Parameter estimates

θ	σ	ρ	ϕ	δ	ψ	λ	J-test
0.5174	0.5718	0.7122	0.0167	0.0373	0.1352	0.0637	0.0253
(0.0217)	(0.0176)	(0.0332)	(0.0094)	(0.0032)	(0.0304)	(0.0146)	(0.8736)

Table 1.3: Local sensitivity of parameters to moments

This table shows the standardized sensitivity of parameter estimates to estimation moments of Andrews et al. (2017). Each row in the table corresponds to a moment used in the estimation, and each row to a parameter.

	θ	ϕ	λ	σ	ρ	δ	ψ
Average investment	0.27		0.343	−0.207	−0.25	0.662	0.452
Average profits	−0.521			−0.367	0.636		
Autocorrelation of profits		0.285	0.295	−0.415	0.49	0.284	0.221
Variance innovation to profits	−0.313			0.381			
Frequency internal financing	0.69	0.795	0.363		0.264	0.512	
Variance internal financing	−0.273	−0.388				−0.34	−0.44
Average external financing	−0.324	0.31	−0.83				−0.928
Variance external financing							0.201

(Blank entries indicate a sensitivity of less than 0.2 in absolute value).

Table 1.4: Effect of the agency conflict

This table reports simulated moments from the model presented in section 1.2 for different values of the ownership parameter γ. All other parameters are fixed at the estimated values in Panel B of Table (1.2).

	$\gamma = 0.3$		$\gamma = 0.6$		$\gamma = 0.9$		$\gamma = 1$
	H	L	H	L	H	L	H,L
Average investment	0.088	0.078	0.086	0.082	0.086	0.085	0.086
Std. Dev. investment	0.326	0.296	0.321	0.308	0.321	0.318	0.322
Serial autocorrelation investment	0.080	0.069	0.078	0.072	0.077	0.076	0.077
Average profits	0.139	0.138	0.139	0.139	0.139	0.139	0.139
Std. Dev. profits	0.091	0.092	0.091	0.092	0.091	0.091	0.091
Serial autocorrelation profits	0.076	0.072	0.076	0.074	0.075	0.075	0.075
Frequency of internal financing	0.380	0.489	0.401	0.446	0.417	0.427	0.424
Std. Dev. internal financing	0.197	0.182	0.196	0.188	0.204	0.201	0.208
Corr. internal fin. and invest.	0.682	0.369	0.630	0.476	0.587	0.554	0.575
Average external financing	0.007	0.029	0.009	0.021	0.012	0.015	0.013
Std. Dev. external financing	0.042	0.121	0.053	0.098	0.065	0.076	0.069

Table 1.5: Effect of diversification

This table reports simulated moments from the model presented in Section 1.2 for different values of the diversification parameter, ρ_ϵ. All other parameters are fixed at the estimated values in Panel B of Table (1.2).

	$\rho_\epsilon = -0.8$		$\rho_\epsilon = -0.3$		$\rho_\epsilon = 0.3$		$\rho_\epsilon = 0.8$	
	$Corr_{ROA} = -0.40$		$Corr_{ROA} = -0.14$		$Corr_{ROA} = 0.10$		$Corr_{ROA} = 0.57$	
	H	L	H	L	H	L	H	L
Average investment	0.093	0.090	0.090	0.087	0.086	0.084	0.080	0.077
Std. Dev. investment	0.356	0.345	0.348	0.341	0.336	0.329	0.308	0.299
Serial autocorr. investment	0.084	0.082	0.079	0.076	0.073	0.070	0.064	0.059
Average profits	0.130	0.129	0.132	0.132	0.133	0.132	0.133	0.133
Std. Dev. profits	0.086	0.086	0.092	0.092	0.093	0.093	0.089	0.090
Serial autocorrelation profits	0.076	0.074	0.074	0.072	0.074	0.073	0.076	0.074
Frequency of internal financing	0.439	0.500	0.425	0.497	0.402	0.490	0.360	0.490
Std. Dev. internal financing	0.268	0.260	0.227	0.223	0.182	0.183	0.117	0.119
Corr. internal fin. and invest.	0.737	0.702	0.647	0.551	0.572	0.382	0.498	0.070
Average external financing	0.005	0.008	0.012	0.022	0.018	0.036	0.022	0.050
Std. Dev. external financing	0.033	0.047	0.066	0.097	0.090	0.144	0.103	0.181

Table 1.6: The value of the internal capital markets

This table reports results of counterfactual experiments. Panel A shows the value added by the internal capital markets to shareholders in firms H and L, as well as the reduction in external financing, for different values of the ownership structure parameter, γ. Panel B shows the value added by the internal capital markets and reduction in external financing for different levels of diversification, measured by the parameter ρ_ϵ. Panel C shows the percentage change in the value added by the internal capital markets caused by a change in two standard deviations on a given parameter.

A. By Ownership Structure

	$\gamma = 0.3$	$\gamma = 0.6$	$\gamma = 0.9$	$\gamma = 1$
Value gain (%)				
Firm H	2.11	1.69	1.64	1.64
Firm L	1.20	1.52	1.62	1.64
External financing reduction (%)				
Firm H	3.93	3.39	2.98	2.86
Firm L	0.35	1.59	2.63	2.86

B. By Diversification

	$\rho_\epsilon = -0.8$	$\rho_\epsilon = -0.3$	$\rho_\epsilon = 0.3$	$\rho_\epsilon = 0.8$	$\rho_\epsilon = 1.0$
Value gain (%)					
Firm H	3.26	2.46	1.88	1.23	0.91
Firm L	3.18	2.12	1.34	0.35	−0.04
Ext. fin. reduction (%)					
Firm H	3.76	3.44	2.84	1.99	1.38
Firm L	3.39	2.42	0.99	−0.79	−2.08

C. Sensitivity of Value

	γ	ρ_ϵ
Firm H	−7.00	−11.95
Firm L	7.42	−18.41

Chapter 2

The determinants of hedging policies: Evidence from a structural estimation

2.1 Introduction

What are the determinants of corporate risk management policies? The risk management literature argues that corporations should pursue hedging activities only in the presence of market imperfections. Theoretically, since the result of hedging is usually to reduce the volatility of target variables, hedging would add value under any convex cost (e.g., bankruptcy costs, progressive tax schedules) or concave payoff (e.g., manager risk aversion, decreasing returns to scale). Consequently, some empirical studies suggest a positive relation between firm value and risk management (e.g., Allayannis and Weston, 2001 and Carter et al., 2006). The specific variables that affect the degree in which firms engage in corporate hedging, and their relative effects on the value created, however, still requires further study.

In this paper, we explore these variables, and specifically, we focus on the interaction between corporate hedging and financing. Reducing distress costs is one of the more cited arguments to motivate corporate hedging (e.g., Smith and Stulz, 1985, Froot et al., 1993, Purnanandam, 2008). We contribute to this literature by developing and estimating a standard neoclassical model of investment for a firm that faces product price uncertainty that can be hedged in order to reduce financing costs. This enables us to quantify the value created by hedging activities and study its determinants.

In our model, a risk-neutral manager decides at every period the level of investment, amounts of debt and equity financing, and risk management choices in order to maximize the equity value of the firm. The risk management policy is implemented by locking in today next period's product price for a fraction of the production. Additionally, the price of debt financing is determined endogenously by a zero-profit condition in a competitive lending market. Since hedging helps reduce the likelihood of distress, it allows the firm to lower its cost of debt financing. Additionally, hedging helps also reduce the volatility of cash flows, which may also the need for costly external financing. Naturally, setting up hedging activities involves its own costs. For instance, it may involve paying risk premiums in the derivative markets, paying commision fees, and wages to the risk management team. Therefore, the manager of the firm faces a trade-off between the benefits of reducing total financing costs and the costs involved in setting up hedging activities.

To confront our model with the data, we study a sample of U.S. upstream oil and gas (O&G) companies covering the years 1996–2013. We choose this sample for two reasons. First, O&G sector firms are all exposed to a common source of risk and on average they hedge a significant fraction of their production (roughly 30% in our sample). This allows us to dig into their risk management policies. Second, focusing on a single industry eliminates significant heterogeneity in firm's policies. This is particularly suited for the structural estimation approach we follow, which otherwise struggles to deal with heterogeneity. Using this dataset we estimate our model by simulated method of moments (SMM). This estimation procedure chooses the structural parameters of the model that make a set of simulated moments as close as possible to their sample counterpart.

We find that three out of the ten simulated moments targeted in the estimation statistically match their empirical counterpart, however, almost all moments are economically close to the data. This suggests that our model is a plausible approximation of what we observe in the data. Furthermore, the parameter estimates are all statistically significant, with the exception of the fixed cost of capital adjustment, the linear cost of equity financing and the parameter governing the risk premium/discount in the derivatives market.

With the estimated model in hand, we are able to perform counterfactual experiments in order to quantify the value created by hedging activities and evaluate their effect on other financial policies. We estimate that hedging increases the average value of the firm by 7.77% of assets. Our results indicate that roughly half of this value created is a consequence of better terms in the access to debt financing when the firm engage in hedging activities, being the remaining value a result of other non-linearities in the model. Furthermore, hedging allows the firm to increase its profits, increase investment by alleviating financial constraints, increase net debt, and increase dividend payments. Comparative statics exercises show that the value created by hedging is most sensitive to the cost of equity financing and to the risk premium/discount in the derivatives market.

Our approach allows us to avoid the typical empirical problems in this literature. Most of the variables in the data, such as investment, financing and risk management policies are endogenous and jointly determined choices, and exogenous shocks to ensure causality are hard to find. With our approach, these variables emerge endogenously from the economic maximization problem in our model. Additionally, it is difficult to estimate underlying quantities that determine the behavior of firms, such as costs of distress, adjustment costs, and parameters governing a firm's productivity process, without assuming some structure describing the firm's behavior. Lastly, quantifying the benefit of risk management requires performing a counterfactual, for which it would be very difficult to find the right pair of equivalent firms in the data. Our theoretical model helps us to overcome this challenges by providing an intuitive and convincing way of performing these counterfactual exercises.

This paper is related to the literature on corporate risk management, and specifically, on the financing motivations for hedging and its effect on other corporate policies. For example, Froot et al. (1993) argue that hedging can add value by ensuring that the firm does not underinvest in positive net present value (NPV) projects because of binding financial constraints. Disatnik et al. (2014) document that cash flow hedging reduces firms' precautionary demand for cash and allows them to rely more on bank lines of credit. Instead, we focus on the effect of hedging on the cost of debt and its implications.

We contribute also to the literature that studies risk management in dynamic settings. For instance, Fehle and Tsyplakov (2005) explore a dynamic model of corporate risk management in continuous time. Consistent with the main prediction in their model, empirically they find a non-monotonic relation between risk management intensity and measures of financial distress. Gamba and Triantis (2014) explore dynamic risk management policies, considering the interactions between liquidity management, hedging activity, and operational flexibility. Their main findings suggest that liquidity management is a more efficient tool for risk management than hedging with derivatives, which reconciles with the evidence of low-value gains attributable to hedging found in some studies. Rampini et al. (2014) study a dynamic model in which firms need collateral in order to raise financing and engage in hedging activities. Their model is able to replicate the empirical cross-sectional regularity that large and less constrained firms engage more in risk management than small and more constrained ones. Our work takes ingredients of this literature and contributes by quantifying the effects of hedging in a framework that tightly connects our model with the data.

The empirical method in this paper is similar to other studies in corporate finance, which estimate structural dynamic models to explore capital structure (e.g., Hennessy and Whited, 2005, DeAngelo et al., 2011, Li et al., 2016), cash management (e.g., Nikolov and Whited, 2014, Bakke and Gu, 2017, Gu, 2017) and executive compensation (e.g., Taylor, 2010, Taylor, 2013, Page, 2018). Different from their work, the goal of this paper is to explore the motivations for risk management, and quantify its value and its effect on other corporate policies.

The rest of the paper is organized as follows. Section 2.2 presents and analyzes the model. Section 2.3 describes the data. Section 2.4 discusses estimation and identification. Section 2.5 present counterfactuals results, and Section 2.6 concludes. The Appendix provides technical details.

2.2 Model

In this section, we present a dynamic investment model in discrete time for an infinitely lived firm which engages in output price risk management. We consider a risk-neutral manager who takes investment, financing, and hedging decisions to maximize the equity value of the firm.

2.2.1 Production technology

The firm uses capital, k, to produce per period profits $\pi(k,z)$, where z is a random shock which captures output price uncertainty. We assume that, without hedge, the profit function is $\pi(k,z) = zk^{\theta} - C(k)$, with $0 < \theta < 1$ and $C(k)$ a fixed cost function. In our applications we parametrize the fixed cost function as $C(k) = \kappa\, k^{ss}$, where $\kappa > 0$ is a parameter, and k^{ss} is the theoretical steady state of capital.[10] The curvature parameter,

[10]The steady state of capital, k^{ss}, equates the marginal cost product of capital, $\partial(k^{ss\theta})/\partial k^{ss}$, with the opportunity cost and depreciation rate, $(r_F + \delta)$. i.e., $k^{ss} = (\theta/(r_F + \delta))^{(1/(1-\theta))}$.

θ, captures decreasing returns of scale. The manager observes the random shock before making investment, financing and risk management decisions. We assume that the random shock follows the AR(1) process in logs

$$\log(z') = -\frac{(1-\rho)\sigma^2}{2(1-\rho^2)} + \rho\log(z) + \epsilon', \ \epsilon \sim N(0,\sigma^2), \tag{2.1}$$

in which a prime indicates a variable in the next period. ϵ is a normally distributed innovation with mean zero and variance σ^2, and ρ is the autocorrelation coefficient. We scale the process for z, such that its unconditional mean is not affected by σ or ρ. This is meant to isolate the effects of other parameters from σ and ρ when we explore comparative statics below. We define the Markov transition function associated to (2.1) as $g(z'|z)$.

The firm's capital investment is denoted by I. Capital is purchased at a price of one, and it depreciates at a rate δ per period, with $0 < \delta < 1$. Therefore, the capital evolution over time is given by

$$k' \equiv (1-\delta)k + I. \tag{2.2}$$

The firm pays a fixed capital adjustment cost whenever it sells capital, denoted by $\Phi(k, I)$. The functional form of the total costs of investment is then

$$\Phi(k,I) = I\,\mathbb{1}_{I>0} + \phi\,I\,\mathbb{1}_{I\leq 0}, \tag{2.3}$$

in which $0 < \phi < 1$ is a positive constant. This specification, which follows Michaels et al. (2016), is equivalent to assume that the firm sells capital at a discount price, ϕ, because sold assets may have limited value on the secondary market.

2.2.2 Risk management

We assume the firm can hedge a fraction, h, of its production. Throughout the paper, we call this fraction the hedge ratio. This means that at each period the firm can lock in the price at which it sells its goods next period. Since we assume all the price uncertainty is captured in the stochastic shock, z, we assume that, if the firm decides today to hedge a fraction h' of tomorrow's production, then tomorrow's profit function is given by

$$\pi(k', h', z, z') = z' k'^{\theta} (1 - h') + (1 - \eta) E[z'|z] k'^{\theta} h' - C(k'), \tag{2.4}$$

where the term $(1 - \eta)E[z'|z]$ represents the forward price agreed upon today. This forward price is the expected price discounted by a constant factor, $(1 - \eta)$, which captures risk premium/discount. Note that next period's profit function depends on z and z', because the hedged part of profits is a function of $E[z'|z]$, the expected value of z' conditional on z. We do not constrain the parameter η to be positive, thus, we are agnostic on whether the forward prices in the oil market are described by *normal backwardation* or *contango*.[11]

2.2.3 Financing

The firm can finance its capital investment with current profits, external debt issues, external equity issues, or a combination of them. External debt takes the form of a defaultable one-period discount bond with face value b'. The interest rate on the bonds is $\tilde{r}(k', b', h', z)$, so that debt proceeds of debt issues are $b'/(1 + \tilde{r}(k', b', h', z))$. As explained below, this interest rate is determined endogenously from a lender's zero-profit condition, which depends on the model's state variables. The firm can also choose to

[11]Note that the term *normal backwardation* refers here to the situation in which the futures price is below the expected future spot price, and *contango* refers to the situation in which the futures price is above the expected future spot price.

keep cash balances, in which case $b' < 0$, and earn the constant rate of return $\bar{r}$, which is exogenously given. Therefore, the interest rate on debt/cash balances, $r(k', b', h', z)$, can be expressed as

$$r(k', b', h', z) = \begin{cases} \tilde{r}(k', b', h', z) & \text{if} \quad b > 0 \\ \bar{r} & \text{if} \quad b \leq 0 \end{cases} \tag{2.5}$$

When the difference between inflow and outflow of resources to the firm, e, is negative, the firm issues equity. When this difference is positive, the firm is distributing dividends to shareholders. Hence, the cash distributions/issuance to shareholders before fees is

$$e(k, k', b, b', h, h', z_l, z) = \pi(k, h, z_l, z) - \Phi(k, I) + \frac{b'}{1 + \tilde{r}(k', b', h', z)} - b \tag{2.6}$$

where we use z_l to denote previous period's shock z.

We assume that for each dollar of external financing raised, the firm must pay a linear cost equal to

$$\Lambda(e(k, k', b, b', h, h', z_l, z)) = \mathbb{1}_{\{e(k,k',b,b',h,h',z_l,z)<0\}} \lambda e(k, k', b, b', h, h', z_l, z), \tag{2.7}$$

where $\mathbb{1}_{\{e(k,k',b,b',h,h',z_l,z)<0\}}$ is an indicator function that equals one when the firm raises funds. This specification is motivated by flotation costs of equity financing.

2.2.4 The loan contract

The pricing of debt follows the approach in Michaels et al. (2016), which is adapted from Cooley and Quadrini (2001) and Hennessy and Whited (2007). We assume the firm borrows from a perfectly competitive debt market, and that lenders are risk-neutral and have an opportunity cost of funds $\bar{r}$. If the firm defaults on its debt, the lender has the ability to liquidate the firm receiving a fraction $(1-\xi)$ of the firm's fixed assets. The share ξ captures, then, bankruptcy costs.

As in Michaels et al. (2016), and unlike Hennessy and Whited (2007), we make the simplifying assumption that repayments to lenders in the form of shares are forbidden in the event of bankruptcy. This means that the future market value of the firm is not collateralizable and the firm's ability to issue debt depends on a net worth covenant (see Gilchrist et al., 2014). Under these conditions, the firm will default when net worth is less than a minimum threshold, below which lenders are not willing to participate in the debt issue because expected recovery rates are too low. We assume this minimum is zero, as lenders would never lend to a negative net worth firm. Noting that net worth is increasing in z, we define a threshold output price, $\hat{z}$, such that the firm choosing policies (k', b', h') will default next period if $z' < \hat{z}$. Therefore, $\hat{z}$ satisfies

$$0 \equiv \pi(k', h', z, \hat{z}) - b' + (1-\delta)\phi k', \tag{2.8}$$

where the right hand side represents the resources available to the firm in order to repay its debt when in no default. Note that in the event of default, capital is valued at its resale price, $(1-\delta)\phi k'$.

The bond discount rate, $\tilde{r}(k', b', h', z)$, is determined by the lender zero profit condition, considering the default condition in (2.8). Therefore, this rate satisfies

$$\frac{b'}{1+\tilde{r}(k', b', h', z)} =$$

$$\frac{1}{1+\bar{r}}\left(\int_0^{\hat{z}} \left(\pi(k', z', h') + (1-\xi)(1-\delta)k'\right) g(z'|z) + (1-G(z'|z))b'\right) \tag{2.9}$$

where $G(z'|z)$ is the cumulative distribution associated to the Markov transition function in (2.1). The left hand side of this equation is the sum of the expected payoffs conditional on default and repayment in continuation, discounted at the lenders opportunity cost.

Figure 2.1 illustrates the effect of the decision variables on the determination of the interest rate. Panel (a) shows the interest rate on debt for the benchmark case, in which output price is at its mean, next period capital stock is at its simulated average, and three different levels of the hedge ratio: 0%, 50%, and 90%. As expected, hedging has the effect of reducing the interest rate paid on the debt, which is one of the main motives the manager has in our model to engage in risk management. Panel (b) shows that for low values of the output price, the effect of hedging on the interest rate is weaker. The three curves get closer together, and the interest rates for the three different levels of hedging converge to the same value faster than in the benchmark case. Panel (c) shows that for low levels of capital stock in the next period, the curve shifts to the left (interest rates begin to increase for lower levels of debt) as net worth decreases.

2.2.5 The objective function

The firm's problem is to choose capital investment, next period's stock of debt/cash balances, and the fraction of output to be hedged, $\{k', b', h'\}$, every period to maximize the expected discounted value of dividends, discounting at the firm's opportunity costs of funds, r_F.

Defining the state variable $w' \equiv b' - (1-\eta)E[z'|z]k'^{\theta}\, h'$, we avoid having to include the previous period output price, z_l, as an additional state variable. Therefore, the state space of the model can be defined simply as (k, w, h, z).

Now, the firm's problem can be expressed recursively by the Bellman equation

$$\begin{aligned} V(k,w,h,z) &= \max_{\{k',w',h'\}} \Big\{ e(k,k',w,b',h,h',z) + \Lambda(e(k,k',w,b',h,h',z)) \\ &\quad + \frac{1}{1+r_F} \int V(k',w',h',z') dg(z'|z) \Big\}, \end{aligned} \tag{2.10}$$

where $V(\cdot)$ corresponds to the firm's equity value conditional on the state variables $\{k,w,h,z\}$, and $dg(z'|z)$ is the transition density of the random shock process, z. The first two terms on the right hand side of equation (2.10) are the equity distributions/issuances and equity issuance costs. The last term represents the discounted expected value of firm in the next period.

2.2.6 Numerical policy functions

In this section, we explore optimal policy functions by numerically solving the dynamic model presented in the previous sections via value function iteration. Details of the numerical solution are described in the Appendix. Figure 2.2 shows optimal responses of investment, debt/cash, hedging, and distribution/issues of equity, to the output price shock, z, for three different levels of current stock of net debt: negative net debt (cash), zero net debt, and positive net debt. Investment is defined as I/k, debt/cash as b'/k, hedge ratio as h'/k, and distributions/issues of equity as e/k. The model is parameterized at the estimated parameters in Panel B of Table 2.3, holding the current stock of capital at its simulated average, the current stock of net debt at either a negative value, zero, or a positive value, the current hedge ratio at zero, and letting the output price shock take values in the interval $[-4\sigma/\sqrt{1-\rho^2}, 4\sigma/\sqrt{1-\rho^2}]$.

For the three levels of current net debt in the plot, the investment response is increasing in the output price. While the investment function is almost identical for the case of negative net debt (cash) and zero net debt, investment is lower for the case of positive net debt. This is because, for low realizations of the output price shock, the firm has to sell capital to pay its current debt. The curves showing next period's net debt for the three levels of current net debt are almost identical. Net debt increases on the output price shock, with the firm with positive net debt taking slightly higher net debt next period.

Next period's hedge ratio decreases with the output price shock. Here, it is interesting to note that the firm which holds positive net debt chooses much higher hedging levels compared to the unlevered firm and to the firm holding cash. This is because low current net worth makes the cost of debt to increase too much if not taking sufficient hedge. On the other hand, as explained below, under the estimated set parameters, the firm never chooses to hold cash, which explains the almost identical hedging policies for the unlevered firm and the firm holding cash.

Finally, the equity distribution/issue policy is practically flat for most of the range of output price shocks. It is only for very high realizations of these shocks, that the firm chooses to increase distributions. Comparing the three firms according to the level of current net debt, the firm holding cash balances chooses to distribute all excess cash (next period net debt is positive and identical to that of a zero net debt firm). On the other hand, the firm holding positive net debt has to even issue a small amount of equity to be able to repay old debt.

Overall, these policy functions show how risk management choices are affected by net worth and the future needs of debt financing.

2.2.7 Comparative statics

We now show how the optimal hedge ratio responds to the parameters in the model. Figure 2.3 depicts these sensitivities. Each panel in this figure plots the mean simulated hedge ratio as a function of a particular parameter while keeping all other parameters constant at their values in Table 2.3. We consider the eight parameters we estimate via simulated method of moments (SMM): the curvature of the profit function, θ, the production fixed cost parameter, κ, the autocorrelation of the shock to profitability and standard deviation of its innovations, ρ and σ, the fixed cost of capital adjustment, ϕ, the linear cost of external equity financing, λ, the bankruptcy cost, ξ, and the risk premium/discount, η. We let the free parameter to move in a given interval centered roughly at the estimate from Table 2.3. θ takes values in the interval $[0.6, 0.95]$, κ in $[0, 0.25]$, σ in $[0.3, 1.1]$, ρ in $[-0.9, 0.9]$, ϕ in $[0, 0.5]$, λ in $[0, 0.3]$, ξ in $[0.03, 1]$, and η in $[0, 0.1]$.

First, we examine the parameters related to the production technology and investment. The relation between the curvature of the profit function, θ, and the hedge ratio is non-monotonically decreasing. Higher curvature of the profit function implies lower average profits and consequently higher demand for external financing and hedging. The same intuition explains the positive relation between the production cost parameter, κ, and the hedge ratio. The autocorrelation coefficient in absolute value is negatively related to the hedge ratio. As this coefficient increases (in absolute value), a greater fraction of next period price is explained by today's price, decreasing the dispersion of cash flows, thus, lowering the firm's demand for hedging. Similarly, the volatility of the innovation to the price shock process has a positive relationship with hedge ratio. As σ increases, dispersion of cash flows increases, so the value of risk management is greater, implying higher firm's demand for hedging. Finally, increasing the convex adjustment of capital cost, ϕ, increases the hedge ratio. As ϕ increases, the firm invests less, resulting in lower profits and higher demand for external financing, which makes hedging more valuable, pushing up the firm's demand for hedging.

Next, we examine the parameters related to financing and risk management. The figure shows a positive relationship between the cost of equity financing, λ, and hedge ratio. Intuitively, as the cost of equity financing increases, the firm substitutes equity financing with debt financing. Since hedging help to reduce the costs of debt, the firm increases its demand for hedging. Next, as the bankruptcy cost, ξ, increases, hedging increases non-monotonically for values of ξ up to roughly 0.9, and sharply decreases after this point. Two opposing effects explain this pattern. First, as bankruptcy costs increase, the demand for debt financing decreases, thus reducing the need for hedging. On the other hand, as debt financing is more costly, the equilibrium level of cash flows decrease, leaving less net worth available as collateral for debt financing, increasing the need for hedging. At the extreme, when ξ is close to one, the firm lowers debt financing and the demand of hedging to almost zero. Finally, the risk premium/discount parameter, η, is negatively related to the optimal hedge ratio. As this parameter increases, hedging becomes more costly, so the demand for hedge decreases.

Consistent with the optimal policies studied in section 2.2.6, these exercises highlight how the hedging policy is affected by two main variables: the availability of net worth as collateral, and the dispersion of cash flows.

2.3 Data

In order to estimate the model, we collect data for a sample of U.S. oil and gas producers from 1996 to 2013. First, we select all the firms in the NAICS code corresponding to "Crude Petroleum and Natural Gas Extraction"[12] from the Compustat Quarterly files. We get quarterly financial data from Compustat and hand-collected hedging positions from 10-K and 10-Q forms filed by listed companies with the Securities and Exchange Commission (SEC). Complete hedging data are not available prior to 1996, thus our sample begins in the first quarter of 1996. We are able to collect this data for 136 firms,

[12]NAICS code equal to 211111.

resulting in a dynamic panel data of 3,319 firm-quarter observations. This is a much larger sample size than what earlier studies in the risk management literature were able to collect (e.g., Tufano, 1996, Carter et al., 2006, Lookman, 2009).

We define investment as the ratio of capital expenditures (*CAPX*) over net property, plant, and equipment (*PP&E*) outstanding in the previous fiscal quarter. Profit is defined as the ratio of operating income before depreciation over PP&E. Net debt is the ratio of the difference between long-term debt and cash and short-term investments over PP&E. Distributions are the ratio of dividend distributions over PP&E. The hedge ratio variable is defined as the ratio of oil hedged over total oil produced. Table 2.1 contains precise variable definitions.

Table 2.2 provides descriptive statistics for firm characteristics and oil production and hedging. To quantify the magnitude of financial characteristics, I compare oil and gas firms to the universe of firms in Compustat for the same period (numbers not tabulated).[13] Firms in the oil and gas industry have higher investment ratio, lower leverage ratios, net debt, distributions, book assets, and similar profit, cash, distribution, and market to book value ratios compared to the average firm in Compustat.

The average firm in the sample produces 1,760 thousand barrels of oil per quarter, of which it hedges 563 thousand barrels, which results in an average hedge ratio of 30.4%. It is worth noting that at least a fourth of the firm-quarter observations have a hedge ratio of zero (and 21% of the firms in the sample never hedge), which means there is heterogeneity in the use of hedging in the oil and gas industry.

[13] I do not consider firms for which the ratio of PP&E over total assets is less than 33% to prevent firms with too low PP&E, which goes in the denominator, contaminate the averages.

2.4 Estimation and identification

In this section we describe the estimation methodology, identification strategy, and estimation results.

2.4.1 Parameters and selection of moments

We estimate most of the parameters using the simulated method of moments (SMM). The lenders' opportunity cost rate, $\bar{r}$, the firm's discount rate, r_F, and the depreciation rate, however, are estimated separately. We set the lenders' opportunity cost rate at 2.6% on an annualized basis, which is the average three-month treasury bill rate. We set the manager's discount rate to be 3.12%, consistent with an effective corporate tax rate of 20%. Finally, we set the depreciation rate to be 14.3% on an annualized basis, which is the average ratio of depreciation to capital stock in our sample.

We define Θ as the vector containing the eight parameters to be estimated using SMM: the curvature of the profit function, θ, the fixed cost of capital adjustment, ϕ, the linear cost of external equity financing, λ, the autocorrelation of the shock to profitability and standard deviation of its innovations, ρ and σ, the bankruptcy cost, ξ, the risk premium/discount, η, and the production fixed cost parameter, κ. The SMM estimation chooses the parameters Θ that minimize some *distance* from a set of simulated moments to the actual data moments. Details of the estimation are described in the Appendix. The set of moments we match includes moments related to the real decisions of the firm and moments related to its financial policy.

On the real decisions side, first, we match the second moment of the rate of investment, which in the model corresponds to I/k. This moment helps identify the investment adjustment cost ϕ. Next, we match the mean of the ratio of profits to capital, zk^{θ}/k. This moment helps identify the profit curvature parameter, θ, as well as the fixed cost of production, κ. We also match the autocorrelation of profits and the variance of its innovation, which are the slope coefficient and error variance from a first-order autoregression of the ratio of profits to capital. These moments identify the autocorrelation and standard deviation of the innovation parameters, ρ, and σ.

The next moments are related to the firm's financial and risk management policies. First, we match the first and second moments of net debt, which we define as b/k. These moments help identify the bankruptcy cost parameter, ξ. We also match the mean of equity distributions, e/k. This moment helps identify primarily the linear cost of equity financing, λ. Finally, we match the first and second moments, as well as the autocorrelation coefficient of the hedge ratio, h/k. These moments help identify the risk premium/discount parameter, η, and capture the firm's risk management policy.

2.4.2 Estimation results

Table 2.3 presents the results of the SMM estimation. Panel A reports actual and simulated moments from the model, as well as t-statistics for their difference. Panel B reports parameter estimates and standard errors.

Panel A shows that the model fits the data reasonably well. Three out of ten moments are statistically identical to their empirical counterparts, however, almost all simulated moments seem to be economically very close to the empirical moments. The model struggles, however, to match the relatively high variance of net debt observed in the data. Additionally, the simulated level of net debt is never negative, which means that under the estimated parameters the firm never chooses to hold cash balances. Importantly, the model fits the average, variance, and autocorrelation of hedge ratio relatively well.

The hypothesis that the model matches all ten moments is not rejected at the 10% (the p-value of the J-test is 0.8851).[14]

Next, we turn to the parameter estimates in Panel B. Most of the estimated parameters are significantly different from zero and comparable to related estimates in the literature. The estimated curvature of the profit function parameter, θ, is in line with recent estimates in Li et al. (2016) for U.S. nonfinancial firms and Gu (2017) for multinationals. The volatility of the innovation to the profitability shock, σ, is much higher, and the autocorrelation coefficient, ρ, is lower than estimates in most of the similar studies. This suggests that firms in the oil & gas sector face relatively higher uncertainty than firms operating in other industries, making risk management relatively more valuable. Although the capital adjustment cost parameter is much lower than in other studies, e.g., Michaels et al. (2016), it is still statistically different from zero.

The estimate of the linear cost of external equity financing is 7.6%, it is statistically significant and somewhat lower than estimates typically obtained in the literature (see DeAngelo et al., 2011). The bankruptcy cost parameter estimate is 64.5%, it is statistically significant, and close to other estimates in the literature (see Michaels et al., 2016). The estimate of the risk premium/discount associated with the hedging activities, η, is 0.99% (discount). The positive sign on this parameter was expected, as a negative parameter could induce unbounded demand for hedge from the firm.

With the estimated parameters in hand, we return now to the issue of parameter identification. Table 2.4 shows the standardized sensitivity of parameter estimates to estimation moments of Andrews et al. (2017). This is a local measure of how sensitive a parameter is to a given moment, and considers information on both how sharply a simulated moment responds to a given parameter and how accurately an empirical

[14] Note that the number of observations in this study is relatively low, and the model could surely be rejected with enough additional data (see Taylor (2013) for this argument).

moment is estimated. The standardized version of this metric lies between -1 and 1, with the most sensitive relations between parameter and moments having larger magnitudes in absolute value. Each row in the table corresponds to a moment used in the estimation, and each column to a parameter. To reduce clutter, the table shows only numbers greater than 0.25 in absolute value.

The computed sensitivities are consistent with the intuition discussed in Section 2.4.1. For instance, the autocorrelation parameter, ρ, is most sensitive to the autocorrelation of profits, and the bankruptcy cost, ξ, is most sensitive to the mean net debt. The variance of net debt does not exceed the threshold for any of the parameters; however, since this is a local sensitivity measure, this moment may still be informative for other ranges of parameters.

2.5 Quantifying risk management benefits

One of the benefits of having an estimated structural model is that it can be used to perform counterfactual experiments. In this section, we carry out counterfactual experiments in which we confront the dynamics of a firm without access to hedging with a firm with the ability to manage risk by engaging in hedging activities. This exercise allows us to quantify the extent in which risk management create value. Also, it enables us to decompose the sources of this value, distinguishing whether it is value created as result of the effect on the interest rate or something else.

Table 2.5 presents results of this exercise. The first column shows simulated moments for the case of a firm that does not engage in risk management. The second column shows simulated moments for the case of a firm that engages in risk management, but assuming lenders do not observe it, so hedging does not affect the pricing of loans. With this, we isolate the part of the benefit that is a result of better terms (price) in the access to debt financing from other effects. The third column shows simulated moments for the case of a firm that engages in risk management and lenders observe it, therefore it captures the full effect of hedging in our model.

As expected, the firm that hedges is able to generate slightly higher profits, 4.89%[15] compared to 4.71% of assets, and reduce the volatility of profits. Roughly a half of the increase in profits and almost two thirds of the decrease in volatility of profits is explained by better terms in the access to debt financing. The firm that hedges is also able to invest slightly more, and results also in an increase in the volatility of investment. This effect captures the arguments in Froot et al. (1993), in which corporate risk management may help alleviate an underinvestment problem. Note that hedging without interest rate effects and hedging with interest rate effects affect the volatility of investment in opposite directions. While this volatility increases in the first case, from 8.88% to 10.25% of assets, it decreases in the second case, from 10.25% to 9.33%.

Risk management allows the firm to increase dividend distributions and reduce the volatility of dividends. Observe that if the manager was risk-averse, instead of risk-neutral as in our model, the benefit of risk management would be greater, as the effect on dividends is not only to increase its expected value but also to reduce the volatility by almost a half. Therefore, we argue that our results on the economic value of hedging can be interpreted as a lower bound. Risk management also allows the firm to increase net debt, from 21.30% to 24.73% of capital, increasing also the volatility of net debt, which confirms the idea that risk management allows the firm to have better access to debt financing.

[15]This number is not exactly the same reported in table 2.3 because, in order to make a fair comparison across columns, and avoid that changes in the mean level of capital contaminate the results, the value of capital in the denominator is the same across the three columns in the table, and corresponds to the mean capital value in the case in which the firm does not have access to hedging (first column). The same applies to the other numbers in the table.

Finally, the estimated overall average value created by risk management is 7.67% of capital, or equivalently an increase of 5.12%. Almost half of this value is a result of better terms in the access to debt financing. The other half of the value created by risk management, 3.77% of assets, is attributed to any other non-linearities in the model, such as the decreasing returns to scale and convex interest rate functions.

Our results on the value created by risk management are in line with other studies. For instance, Allayannis and Weston (2001) estimate the value created by risk management in approximately 5% on average for their sample of non-financial multinationals, and Carter et al. (2006) estimate that the value created is between 5% and 10% for airlines firms hedging their exposure to oil price with derivatives. On the other hand, Gamba and Triantis (2014) estimate that the value of hedging with derivatives would be no more than 2% on average, which they argue is consistent with other studies failing to find significant value creation attributable to hedging (e.g., Guay and Kothari, 2003 and Jin and Jorion, 2006), although they recognize this number could be significantly higher for firms facing a key exposure which could be effectively hedge, as in the case of firms in the oil & gas industry.

Now, we explore how the value created by hedging changes with the parameters in the model. As we observed in Figure 2.3, the hedging policy is most sensitive to the parameters θ, σ, λ, ξ, and η. Therefore, we restrict our analysis to these parameters. As in table 2.5, we split the total value of hedging in two, the part that is a result of the effect of hedging on the cost of debt financing, and all other effects. Figure 2.4 shows these exercises, where the solid line represents the total value of hedging and the dashed line represent the value of hedging when we assume that lenders do not observe hedging policies.

The value of hedging slightly increases with θ, as opposed to the mean of the hedge ratio that decreases with θ. On the other hand, the total value of hedging as a function of the volatility of shocks, σ, is almost flat. However, the fraction of this value associated with the effect of hedging on debt cost decreases with the volatility, σ, i.e., for low values of σ, almost all value of hedging is a result of its effect on the interest rate. For high values of σ, most of the value of hedging is a result of the reduction in the need for financing, or other non-linearities in our model.

The relation between the value of hedging and the bankruptcy cost, ξ, is non-monotonic. For values of ξ up to about 0.75, this relationship is almost flat. It peaks around 0.8 (the estimated parameter ξ is 0.78) and then it falls to almost zero. The intuition behind this is that for values of the bankruptcy above a certain threshold, the firm's debt policy, which is not to hedge, does not change. Therefore hedging, which affects the total cost of debt financing, loses its value.

2.6 Concluding remarks

In this paper, we estimate a structural model of investment for a firm exposed to output price risk, which can be hedged using derivatives. In our model, we endogenize the cost of debt, which is affected by the firm's risk management policies. Hedging, therefore, creates value for the company by reducing the cost of debt. Additionally, since hedging has the effect of reducing the variability of the cash flows generated by the firm, it creates value by exploiting any convex cost and concave payoff in our model.

We estimate the value of hedging in 7.67% of assets. Roughly, half of this value is a result of the effect of hedging on the cost of debt, the rest of the value being related with other non-linearities in the model.

Comparative statics exercises suggest that the variables that most affect hedging policies are the volatility of internal cash flows, capital adjustment costs, costs of equity financing, and risk premium/discount in the derivatives market. Consequently, the value created by hedging is most sensitive to these same variables.

Finally, one limitation of this study is that our model considers only one of the many motivations for firms to engage in hedging, namely, the effect it has on bankruptcy costs, and therefore on the cost of debt. For instance, we do not study a risk-averse manager, therefore we consider our estimates could represent a lower bound for the true value created by risk management.

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Appendix

Appendix 2.A Model solution

To solve the model numerically, we start by discretizing the state space $\{k, w, h, z\}$. To discretize $AR(1)$ processes for z, we approximate it into a discrete-state Markov chain using the method in Tauchen (1986). We use a grid with 15 evenly spaced points on the interval $[-4\sigma/\sqrt{1-\rho^2}, 4\sigma/\sqrt{1-\rho^2}]$.

The grid for the capital stock has 80 points with geometrically increasing intervals at a rate of δ. This grid is centered at the steady state value of capital for a firm operating with no financing or capital adjustment costs. The grid for w has 31 equally spaced points in the interval $[-k^{\max}/2, k^{\max}]$, where $k^{\max}$ denotes the maximum value in the capital grid. The limits of the w grid are arbitrarily chosen so that its simulated values lie always between them. We let the choice of w take 10 equally spaced points between the grid points, for which we linearly interpolate the value function. Finally, the grid for the hedge ratio has 15 evenly spaced points between zero and one.

We find the solution to the Bellman equation in (2.10) by iteration of the value function, which gives a value function $V(k, w, h, z)$ and the optimal policy functions $\{k', w', h'\}$.

Appendix 2.B Estimation

The SMM estimator of the parameter vector Θ is

$$\hat{\Theta} = \arg\min_{\Theta} g_n(\Theta)' \widehat{W} g_n(\Theta),$$

with

$$g_n(\Theta) = \left[\widehat{M}(x) - \frac{1}{S} \sum_{s=1}^{S} \widehat{m}\left(y_s, \Theta\right) \right],$$

where $\widehat{M}(x)$ is a vector of moments estimated using the data, x, $\hat{m}$ is the sth vector of corresponding moments using the simulated data, y_s, S is the number of simulations, and $\widehat{W}$ is a positive definite matrix that converges in probability to a deterministic positive definite weighting matrix. To remove heteregeneity in the panel data, all means are computed using raw data, all variances are computed using demeaned data within the firm level, and autocorrelations are computed following the double differences approach in Han and Phillips (2009). We use the optimal weighting matrix $\widehat{W} = \left[n\,\mathrm{var}(\widehat{M}(x))\right]^{-1}$. To calculate the covariance matrix of empirical moments, $\mathrm{var}(\widehat{M}(x))$, we follow the approach propossed by Erickson and Whited (2000), in which we covary the influence functions, $\psi_{\widehat{M}(x)}$.

The estimated simulated moments, $\hat{m}(y_s, \Theta)$, are estimated from simulated samples of length n, which are generated using the optimal policy functions from the problem (2.10). To remove the effect of initial values, I simulate the model for 100 periods and drop the first 60.

Applying the result of Pakes and Pollard (1989) with the optimal weighting matrix, we get

$$\sqrt{n}\left(\widehat{\Theta} - \Theta\right) \quad \xrightarrow{d} \quad \mathcal{N}\left(0, \mathrm{avar}(\widehat{\Theta})\right),$$

in which

$$\mathrm{avar}(\widehat{\Theta}) \quad = \quad \left(1 + \frac{1}{S}\right)\left(\Gamma' \widehat{W} \Gamma\right)^{-1},$$

where $\Gamma = \operatorname*{plim}_{n\to\infty} \partial\, \hat{g}_n(\Theta)/\partial\Theta'$, which I numerically estimate differentiating $\hat{g}_n(\hat{\Theta})$ with respect to Θ.

Finally, the test of the model's overidentifying restrictions is

$$\left(\frac{nS}{1+S}\right)\left(g_n(\Theta)' \widehat{W} g_n(\Theta)\right) \xrightarrow{d} \chi^2_{p-q}$$

where p is the number of moments, and q is the number of parameters.

Figure 2.1: Loan interest rate

This picture compares the interest rate on debt as a function of Net Debt in the next period for three levels of hedging. Panel (a) depicts the benchmark case, in which output price is at its mean and next period capital stock is at its simulated average. Panel (b) plots the case of lower current output prices. Panel (c) shows the case of lower future capital stock.

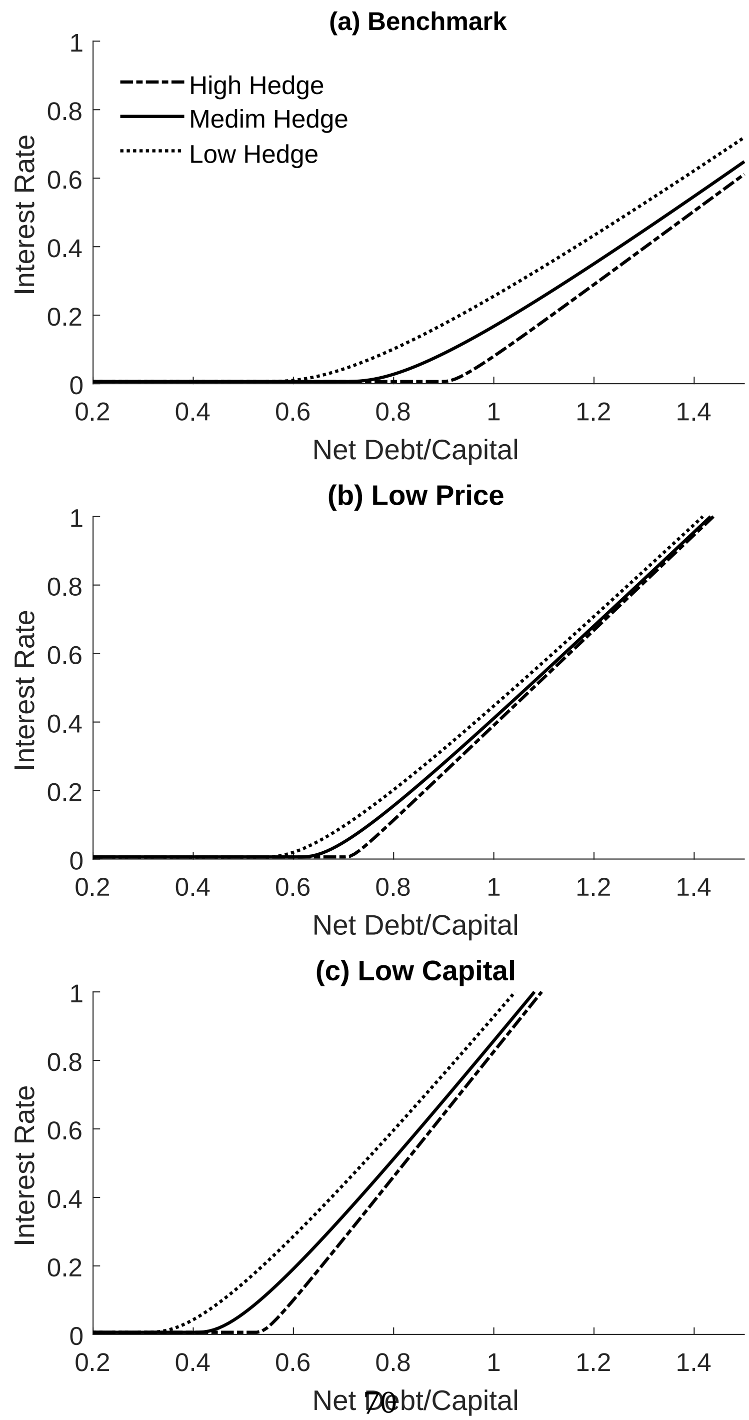

Figure 2.2: Policy functions

This picture compares optimal investment and financial policies as a function of the log of the output price for three levels of current Net Debt: negative (cash), zero, and positive. All values are normalized by the current stock of capital.

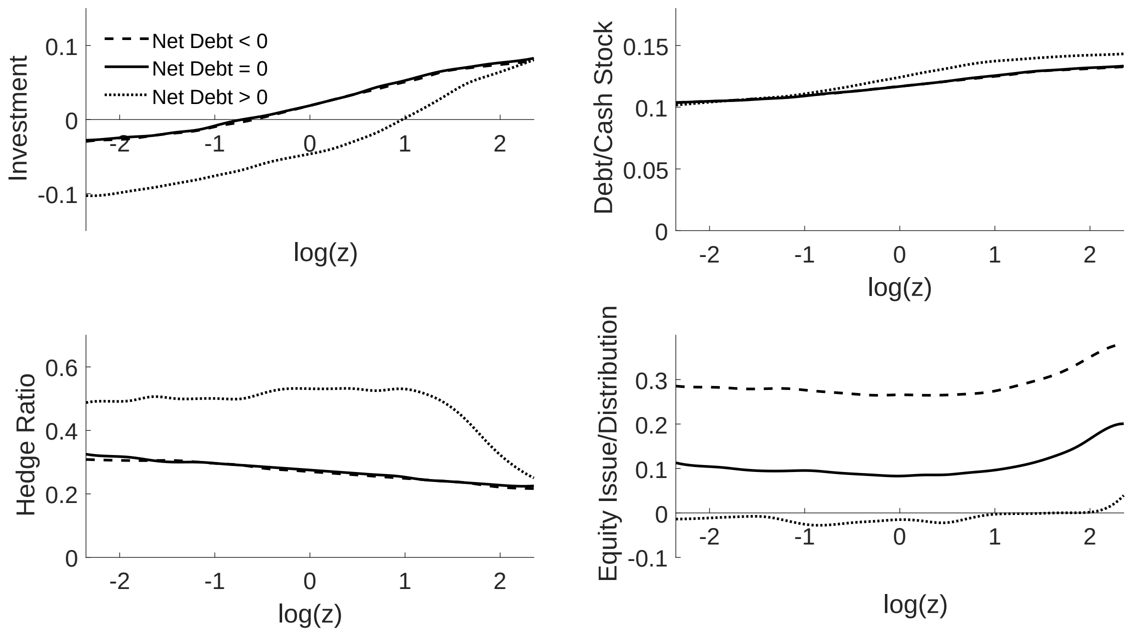

Figure 2.3: Comparative statics

This figure plots the simulated mean hedge ratio as a function of the model parameters. θ is the curvature parameter of the profit function, and κ is the production fixed cost parameter. ρ is the serial autocorrelation of the log of profit shocks, and σ is the standard deviation of their innovations. ϕ is the convex capital adjustment cost. λ is the linear cost of equity financing, and ξ is the bankruptcy cost. η is the risk premium/discount parameter.

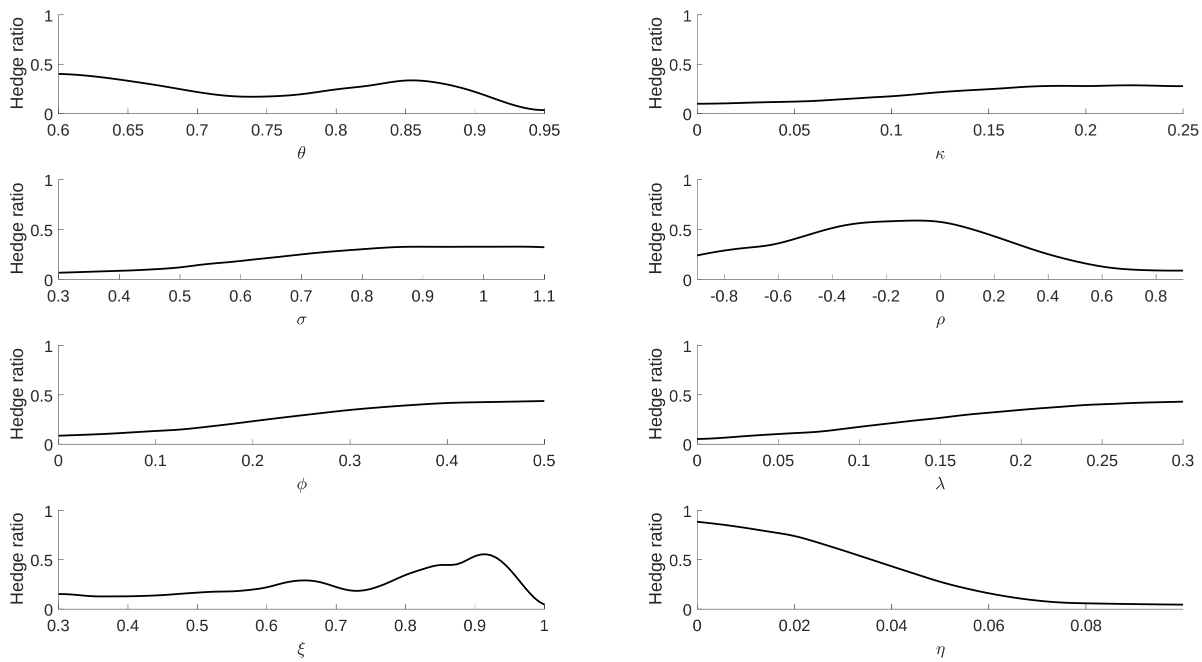

Figure 2.4: Sensitivity of value

This figure depicts how the value of hedging as a fraction of assets (solid line) changes with some of the model parameters. The dashed line represents the value of hedging under the assumption that lenders do not observe the hedging policy. θ is the curvature parameter of the profit function, and σ is the standard deviation of the log of profit shocks. λ is the linear cost of equity financing, ξ is the bankruptcy cost, and η is the risk premium/discount in the derivatives markets.

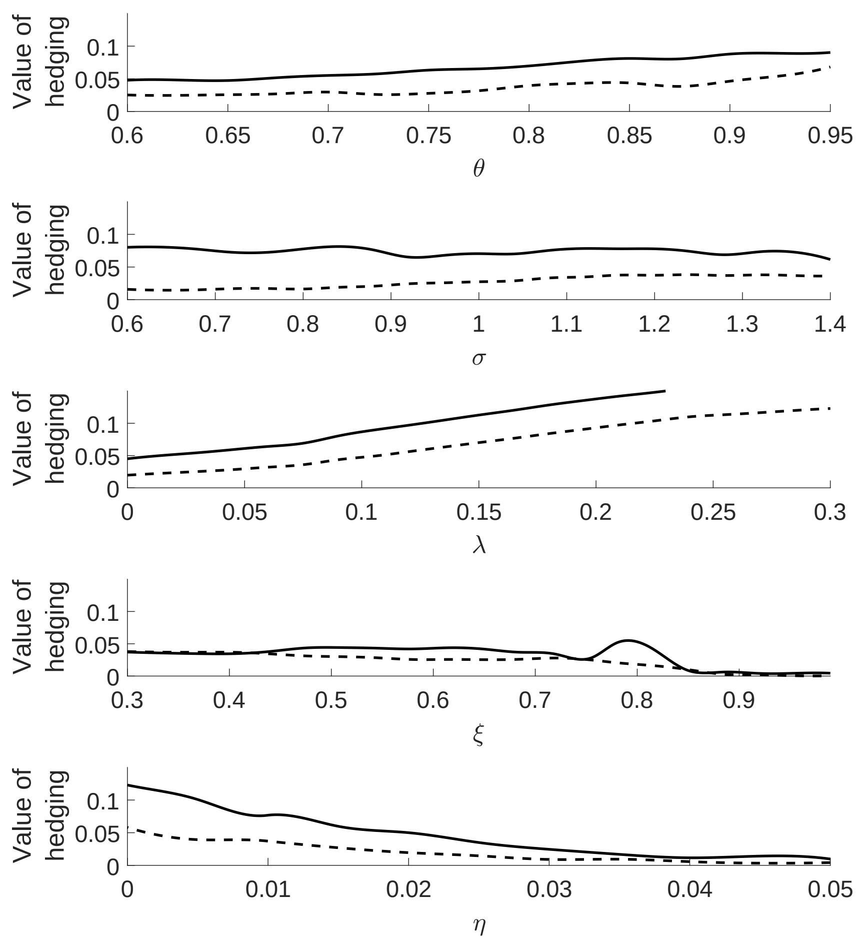

Table 2.1: Variable definitions

This table presents definitions and data sources for variables used. Compustat provides Cash Dividends (dvy) and Purchase of Common and Preferred Stock (prstkcy) for the year to date. Hence, their quarterly counterparts (dvq and prstkcq) equal the yearly variable for the first fiscal quarter, and the first time difference for the second, third, and fourth fiscal quarters.

Variable	Definition
Investment	(Capital Expenditures (capxq) − Sale of Property (sppeq)) / Lagged Property Plant and Equipment - Total (Net) (ppentq)
Profit	Operating Income Before Depreciation (oibdpq) / Property Plant and Equipment - Total (Net) (ppentq)
Cash	Cash and Short-Term Investments (cheq) / Property Plant and Equipment - Total (Net) (ppentq)
Leverage	Long-Term Debt - Total (dlttq) / Property Plant and Equipment - Total (Net) (ppentq)
Net Debt	(Long-Term Debt - Total (dlttq) − Cash and Short-Term Investments (cheq)) / Property Plant and Equipment - Total (Net) (ppentq)
Distributions	(Quarterly Cash Dividends (dvq) + Dividends / Preferred/Preference (dvpq) + Quarterly Purchase of Common and Preferred Stock (prstkcq)) / Property Plant and Equipment - Total (Net) (ppentq)
Book Equity	Shareholders' Equity - Total (seqq) + Deferred Taxes and Investment Tax Credit (txditcq) − Preferred/Preference Stock (Capital) - Total (pstkq)
Book Debt	Assets - Total (atq) − Book Equity
Market to Book Value	(Common Shares Outstanding (cshoq) × Price Close - Quarter (prccq) + Book Debt) / Assets - Total (atq)
Hedge Ratio	Ratio of the number of barrels of oil hedged and the number of barrels of total oil production.

Table 2.2: Summary statistics

This table reports summary statistics for firm characteristics. The sample covers 134 U.S. oil and gas firms from 1996 to 2013.

	Mean	SD	25%	50%	75%	N
Investment and Financial Characteristics (COMPUSTAT)						
Investment	0.087	0.100	0.034	0.062	0.107	4,959
Profit	0.043	0.081	0.030	0.052	0.079	4,991
Cash	0.074	0.115	0.008	0.026	0.080	5,079
Leverage	0.359	0.276	0.145	0.341	0.518	5,079
Net Debt	0.201	0.507	0.074	0.290	0.469	5,072
Distributions	0.005	0.011	0.000	0.000	0.004	4,556
Book Assets (in billions)	2.377	6.831	0.054	0.304	1.280	5,095
Market to Book Value	1.588	0.812	1.090	1.361	1.784	4,903
Oil Production and Hedging						
Oil Production ('000 bbl)	1,760.2	4,095.0	60.9	302.5	1,564.0	4,049
Oil Hedged ('000 bbl)	562.9	1,449.1	0.0	35.0	360.0	3,573
Hedge Ratio	0.304	0.320	0.000	0.227	0.540	3,319

Table 2.3: Estimation results

This table presents estimation results of the model presented in Section 2.2 using the simulated method of moments procedure (SMM). Panel A shows actual and simulated moments and the t-test statistic for the individual moment conditions. Panel B reports parameter estimates and standard errors in parenthesis. θ is the curvature parameter of the profit function, and κ is the production fixed cost parameter. ρ is the serial autocorrelation of the log of profit shocks, and σ is the standard deviation of their innovations. ϕ is the convex capital adjustment cost, and ξ is the bankruptcy cost. η is the risk premium/discount parameter, and ψ is the hedge adjustment cost.

A. Moments

	Actual moments	Simulated moments	t-test
Variance of investment (I/k)	0.0079	0.0115	−7.9542
Average profits (zk^θ/k)	0.0464	0.0431	2.5596
Autocorrelation of profits (zk^θ/k)	0.3592	0.2955	0.8879
Variance of the innovation to profits (zk^θ/k)	0.0034	0.0037	−1.1364
Mean net debt (b/k)	0.2164	0.2313	−1.7982
Variance net debt (b/k)	0.1036	0.0006	17.8479
Average equity distributions (e/k)	0.0042	0.0055	−8.0277
Mean hedge ratio (h/k)	0.3032	0.3466	−7.7656
Variance hedge ratio (h/k)	0.0467	0.0574	−6.9032
Autocorrelation of hedge ratio (h/k)	0.6248	0.1920	8.7170

B. Parameter estimates

θ	κ	σ	ρ	ϕ	λ	ξ	η	J-test
0.8288	0.0078	1.2244	0.3700	0.2074	0.0761	0.7794	0.0099	0.2441
(0.0179)	(0.0014)	(0.0406)	(0.0599)	(0.0044)	(0.0320)	(0.0032)	(0.0183)	(0.8851)

Table 2.4: Local sensitivity of parameters to moments

This table shows the standardized sensitivity of parameter estimates to estimation moments of Andrews et al. (2017). Each row in the table corresponds to a moment used in the estimation, and each row to a parameter.

	θ	κ	σ	ρ	ϕ	λ	ξ	η
Variance of investment					−0.27	−0.35		
Average profits	−0.35	0.30	0.27	−0.39	−0.27	−0.42	0.33	0.28
Autocorrelation of profits	0.27		0.34	0.91	0.36	0.79	−0.56	0.31
Variance of the innovation to profits	−0.35	0.40	0.52		0.32	0.26	−0.26	0.50
Mean net debt			0.35		0.34		−0.77	
Variance net debt								
Average equity distributions								0.31
Mean hedge ratio	−0.25							
Variance hedge ratio		0.33			0.29	0.27		0.28
Autocorrelation of hedge ratio	−0.25		−0.33					−0.31

(Blank entries indicate a sensitivity of less than 0.25 in absolute value).

Table 2.5: Counterfactuals

This table presents the results of counterfactual exercises. The first column shows simulated moments for the case of a firm that does not engage in risk management. The second column shows simulated moments for the case of a firm that engages in risk management, but lenders do not observe it. The third column shows simulated moments for the case of a firm that engages in risk management and lenders observe it.

	No Hedge	No hedge effect on loan rate	Full hedge effect
Average profits (π/k)	4.71	4.81	4.89
Std. dev. profits (π/k)	13.54	11.32	7.46
Average investment (I/k)	3.40	3.48	3.57
Std. dev. investment (I/k)	8.88	10.25	9.33
Average dividends (e/k)	1.28	1.29	1.32
Std. dev. dividends (e/k)	10.84	8.94	5.64
Average net debt (b/k)	21.30	23.07	24.73
Std. dev. net debt (b/k)	5.95	7.61	8.13
Incremental value ($\Delta V/k$)		3.77	7.67